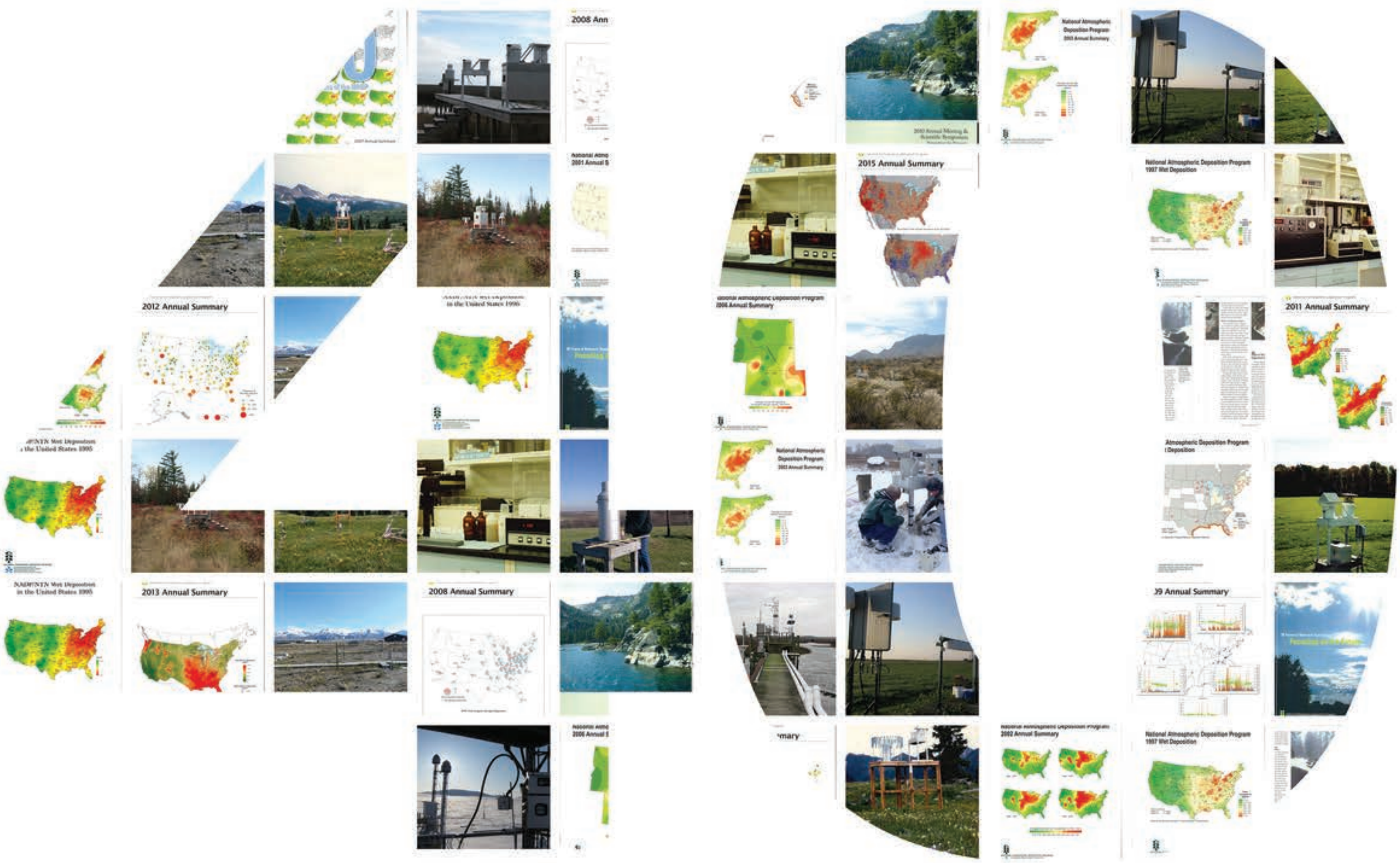
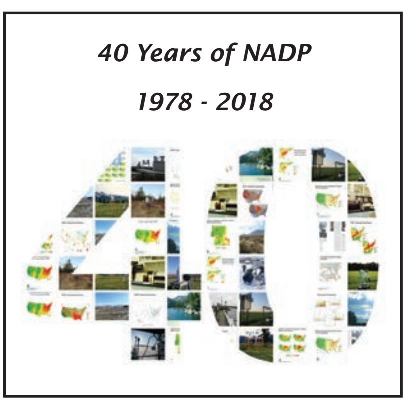
National Atmospheric Deposition Program

2017 Annual Summary

40 Years of NADP
1978 - 2018





On the cover: 2018 is the 40th Anniversary of NADP. The collage of maps and site photos represents the expansive history of what many consider to be the "gold standard" of national environmental monitoring programs.

When referencing maps or information in this report, please use the citation: National Atmospheric Deposition Program, 2018. National Atmospheric Deposition Program 2017 Annual Summary. Wisconsin State Laboratory of Hygiene, University of Wisconsin-Madison, WI.

Contents

2017 Highlights

The National Atmospheric Deposition Program (NADP) provides fundamental measurements that support informed decisions on environmental and public health issues related to precipitation and atmospheric deposition chemistry, as well as advancing understanding of atmospheric processing, through the measurement of ammonia, mercury, and emerging species of concern. NADP data are relevant to scientists, educators, policymakers, and the public. All data are available on the NADP website (http://nadp.slh.wisc.edu). Products available on this site include seasonal and annual averages, time series trend plots, and maps of concentration and deposition.

The NADP is composed of five networks, including the National Trends Network (NTN), the Atmospheric Integrated Research Monitoring Network (AIRMoN), the Mercury Deposition Network (MDN), the Atmospheric Mercury Network (AMNet), and the Ammonia Monitoring Network (AMoN). The table below summarizes the number of measurements from each network in 2017.

Summary of 2017 Network Measurements

Network	Measurements	Period	No. of sites
NTN	13,525	weekly	264
MDN	5,042	weekly	99
AIRMoN	829	daily	4
AMNet	68,044	hourly/ 2-hourly	18
AMoN	2,682	two week	101

New Program Office and Central Analytical Laboratory

Beginning in late 2017 and completed in mid-2018, the NADP Program Office (PO) and Central Analytical Laboratory (CAL) moved from their longtime home at the University of Illinois Urbana-Champaign, Illinois State Water Survey (UI ISWS) to the University of Wisconsin–Madison, Wisconsin State Laboratory of Hygiene (WSLH). The work performed by the UI ISWS has been instrumental in the success of NADP. The dedication of UI ISWS staff over the past 40 years is greatly appreciated by the NADP Executive Committee, program sponsors, policymakers and scientists that use the data. The NADP expects to continue meeting the high standards of operation at the WSLH. The WSLH PO and CAL will continue to improve and advance the program, supporting the development of the next generation of deposition monitoring, positioning the NADP to continue as one of our nation's premier monitoring programs for the next 40 years and beyond.

UW campus and the isthmus in Madison, WI

Highlights:

- The successful transition of the PO and CAL from the University of Illinois Urbana-Champaign to the University of Wisconsin-Madison began in late 2017 and was completed in mid-2018. The transition was seamless, with no data gaps occurring during the transition period and data quality continuing to meet the high standards established by NADP. The transition included transferring PO and Network Equipment Depot (NED) records, supplies, and equipment from Champaign, IL to Madison, WI. In addition, a comprehensive Laboratory Readiness Verification Plan was executed and the Wisconsin CAL performed quite well, meeting all performance metrics.

- The NADP supported 213 publications through data support and PO and CAL outreach. These publications included:
    - ◊ 25 Doctoral Dissertations
    - ◊ 7 agency reports
    - ◊ 1 article in the journal *Science, and*
    - ◊ 1 article in the journal *Nature.*
- The Mercury Litterfall Initiative with U.S. Geological Survey (USGS) scientists completed its fifth year of operation. Twenty-six sites collected litterfall (e.g., leaves, twigs, etc.) for subsequent mercury measurements. These important results have garnered the support for making Litterfall a permanent network.
- The Total Deposition Science Subcommittee (TDEP) continued its work with U.S. Environmental Protection Agency (USEPA) scientists to estimate dry deposition of nitrogen, sulfur, and other analytes.
- NADP collaborated with Utah State University to monitor dry deposition as part of a pilot study. This study continues to expand and will generate valuable dry deposition data.
- NADP continued to work with the Council of State and Territorial Epidemiologists (CSTE) on a possible monitoring network for airborne allergen tracking. Airborne allergens are important as they contribute to allergic rhinitis (i.e., hay fever) and asthma. Other participants in this work include the National Oceanic and Atmospheric Administration (NOAA), USEPA, and the Centers for Disease Control and Prevention.
- NADP continued working with the National Park Service, USGS, USEPA, Colorado Department of Public Health and Environment, Colorado State University, and the Longmont and Boulder Valley Conservation Districts to address the effects and trends of nitrogen deposition and related air quality issues at Rocky Mountain National Park (RMNP). The Rocky Mountain National Park Initiative works to address nitrogen deposition concerns and the 2017 data generated from this collaboration was used to develop the draft 2017 *Monitoring and Tracking Wet Nitrogen Deposition at Rocky Mountain National Park* report.

40 Years of NADP: Historical Legacy and the Future

For forty years the NADP has been the premier monitoring network for assessing spatial and temporal trends of atmospheric deposition of acids, nutrients, and base cations in precipitation across North America.

ACID RAIN

By Gene E. Likens, F. Herbert Bormann, and Noye M. Johnson

European scientists have found that rain in northwestern Europe shows a trend toward increased acidity, particularly over the past fifteen years. The tendency appears linked to mounting levels of certain gaseous pollutants such as sulfur and nitrogen oxides, which can be converted chemically in the atmosphere to strong acids. Although the trend appears to pose no apparent threat to health, it can do considerable damage to man-made structures and equipment, and more importantly it has serious implications for ecological systems.

Data indicating this trend are expressed in what are called pH values. These values are a measure of hydrogen ion activity. Briefly, water slightly ionizes (is converted into ions, which are electrically charged particles), yielding hydrogen and hydroxyl ions. When the activity of these ions is equal, water is neither acid nor alkaline and is said to be neutral. This neutrality point is represented by the pH value 7, which actually varies slightly according to temperature. Water becomes increasingly acid at pH values below 7, increasingly alkaline at values above 7. There are tenfold differences between each unit. Thus, pH 6 is ten times more acid than pH 7, pH 5 is 100 times more acidic than pH 7, and so on.

Distilled water in contact with carbon dioxide in the air becomes slightly acid since carbon dioxide combines with water to form carbonic acid. Normally, the pH of rainwater, regulated only by carbon dioxide gas in the atmosphere, would be 5.7 or only slightly acid.[1] Recent European studies, however, have reported increasing quantities of much stronger acids in rain and snow, producing pH values between 3 and 5. The presence of these acids

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March 1972 33

As early as the mid-1600's the negative effect of emissions on plants and people were being noted; and in 1872 the first use of the term "acid rain" was applied to describe precipitation influenced by industrial emissions. Research throughout Europe and North America, including work by Svante Odén, Eville Gorham, and Robert Smith continued to expand the understanding of acid and nutrient deposition and transport on plants and animals.

Throughout the 1960's and 70's and beyond, research conducted by numerous researchers highlighted the importance of acid rain on our environment and the need for an environmental monitoring network to document the impacts on water quality and ecosystems. Dr. Ellis B. Cowling's, 1982 paper in *Environmental Science & Technology*, "Acid precipitation in historical perspective", details the key steps and people involved in identifying acid deposition impacts and monitoring that led to the NADP as we know it today.

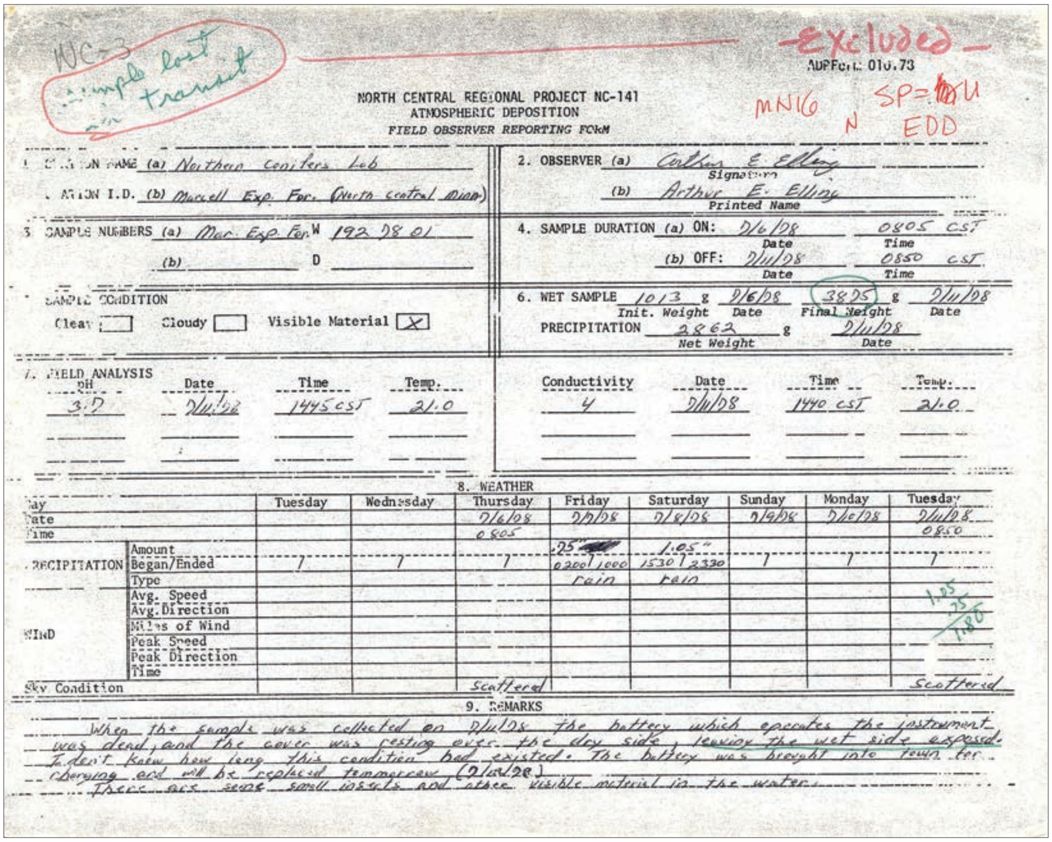
Dr. Gene Likens and his colleagues at Hubbard Brook (NH02) and others such as Charles Cogbill, James Galloway, Carl Schofield, Ellis Cowling, and David Shriner (among many others) revealed the linkage between acid deposition, air pollution sources, and impacts to ecosystems.

This research continues on a global scale. NADP and the numerous supporters, site operators, data users, policy makers, and organizational members have demonstrated the importance of long term observations and high quality data sets to support informed decisions to improve the quality of life, protect the environment, and reduce risk and negative economic impacts associated with emissions to the atmosphere.

NADP's role is crucial for this understanding and will continue to be a key factor for evaluating deposition impacts for the next 40 years.

NADP started with just a handful of sites in 1978, and has grown to over 260 NTN sites participating in the program. This participation has led in part, to 100's of theses and dissertations, and 1000's of peer reviewed publications for which the impact on our understanding of the environment is immeasurable.

NADP continues to expand and evolve, leveraging the networks' broad reach, to gain a better understanding of mercury and ammonia deposition, and supporting researchers and policymakers to identify and monitor the next key environmental parameters that link the atmosphere, precipitation, and ecosystems, leading to informed policy and science decisions.



NC-3 sample lost in transit

Excluded

ADPForm 010.73

MN16 N SP=NU EDD

NORTH CENTRAL REGIONAL PROJECT NC-141
ATMOSPHERIC DEPOSITION
FIELD OBSERVER REPORTING FORM

1. STATION NAME (a) Northern Conifers Lab
STATION I.D. (b) Marcell Exp. For. (North central Minn)

2. OBSERVER (a) Arthur E. Elling — Signature
(b) Arthur E. Elling — Printed Name

3. SAMPLE NUMBERS (a) Mar. Exp. For. W 192 78 01
(b) ______ D ______

4. SAMPLE DURATION (a) ON: 7/6/78 (Date) 0805 CST (Time)
(b) OFF: 7/11/78 (Date) 0850 CST (Time)

5. SAMPLE CONDITION
Clear [ ] Cloudy [ ] Visible Material [X]

6. WET SAMPLE 1013 g (Init. Weight) 7/6/78 (Date) 3875 g (Final Weight) 7/11/78 (Date)
PRECIPITATION 2862 g (Net Weight) 7/11/78 (Date)

7. FIELD ANALYSIS

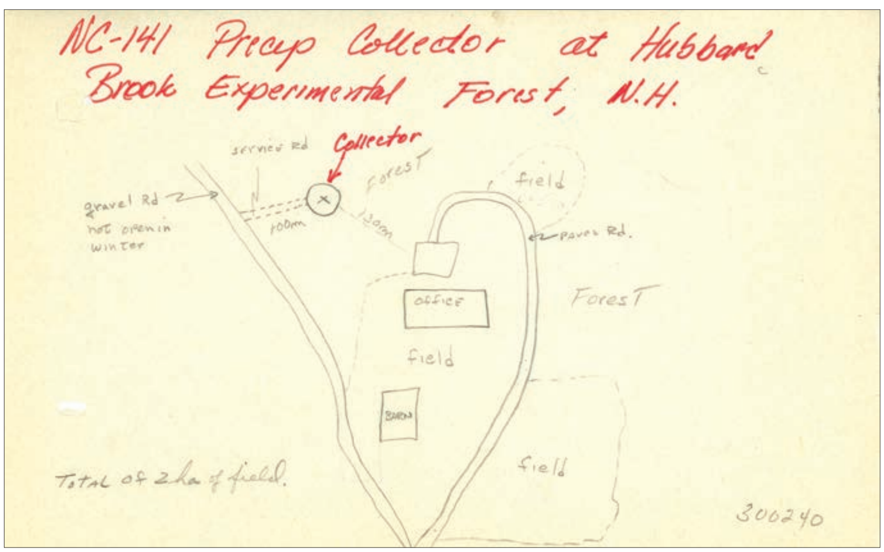
pH	Date	Time	Temp.	Conductivity	Date	Time	Temp.
3.7	7/11/78	1445 CST	21.0	4	7/11/78	1440 CST	21.0

8. WEATHER

		Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday
Day									
Date				7/6/78	7/7/78	7/8/78	7/9/78	7/10/78	7/11/78
Time				0805					0850
PRECIPITATION	Amount				.25"	1.05"			
	Began/Ended	/	/	/	0200 / 1000	1530 / 2330	/	/	/
	Type				rain	rain			
WIND	Avg. Speed								1.05
	Avg. Direction								.75
	Miles of Wind								1.80
	Peak Speed								
	Peak Direction								
	Time								
Sky Condition				Scattered					Scattered

9. REMARKS

When the sample was collected on 7/11/78 the battery which operates the instrument was dead, and the cover was resting over the dry side, leaving the wet side exposed. I don't know how long this condition had existed. The battery was brought into town for charging and will be replaced tommorrow (7/12/78).
There are some small insects and other visible material in the water.



TOP - One of the first three NADP Field Observer Reporting Forms. This one is from MN16 - Marcell Experimental Forest in Itasca, MN – collected in July 1978.

BOTTOM - Original drawing for NADP Hubbard Brook site application.

NADP Background

The NADP was established in 1977 under State Agricultural Experiment Station (SAES) leadership to address the problem of atmospheric deposition and its effects on agricultural crops, forests, rangelands, surface waters, and other natural and cultural resources. In 1978, sites in the NADP precipitation chemistry network first began collecting weekly, wet-only deposition samples. Chemical analysis was performed at the Illinois State Water Survey's Central Analytical Laboratory, located at the University of Illinois at Urbana-Champaign, while the Program Coordinator was housed at Colorado State University. The network was established to provide data on amounts, temporal trends, and geographic distribution of the atmospheric deposition of acids, nutrients, and base cations by precipitation.

Initially, the NADP was organized as SAES North Central Regional Project NC-141, which all four SAES regions further endorsed in 1982 as Interregional Project IR-7. A decade later, IR-7 was reclassified as the National Research Support Project No. 3 (NRSP-3), which it remains to this day. The last renewal was in Federal Year 2017 and will be renewed in 2019 through UW-Madison Research and Sponsored Programs. NRSP projects are multistate activities that support research on topics of concern to more than one state or region of the country. Multistate projects involve the SAES in partnership with the USDA National Institute of Food and Agriculture (NIFA) and other universities, institutions, and agencies. In October 1981, the federally supported National Acid Precipitation Assessment Program (NAPAP) was established to increase understanding of the causes and effects of acidic precipitation. This program sought to establish a long-term precipitation chemistry network of sampling sites away from point source influences. Building on its experience in organizing and operating a national-scale network, the NADP agreed to coordinate operation of NAPAP's National Trends Network. Later, to benefit from identical siting criteria, operating procedures, and a shared analytical laboratory, NADP and NTN merged with the designation NADP/NTN. This merger brought substantial new federal agency participation into the program. Many NADP/NTN sites were supported by the USGS, NAPAP's lead federal agency for deposition monitoring.

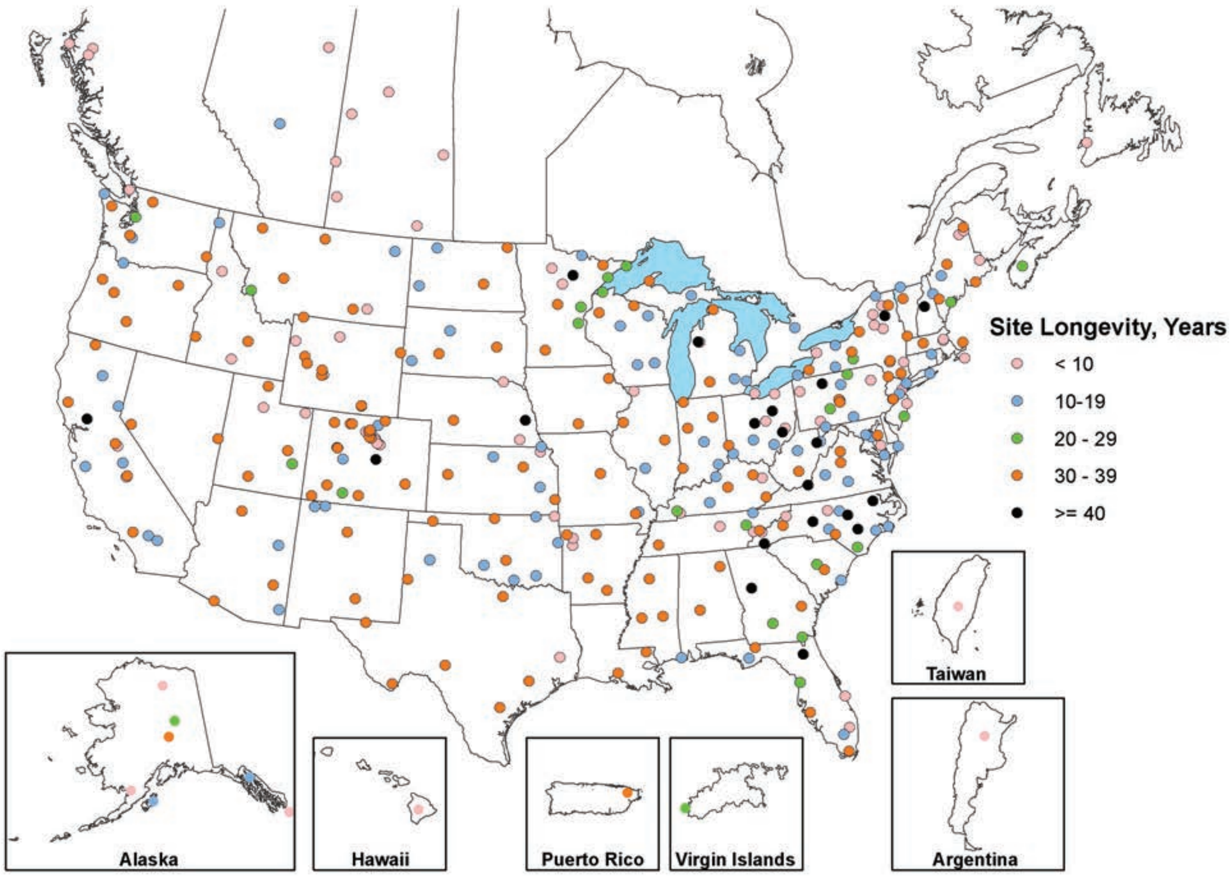
In October 1992, the AIRMoN was formed from the Multistate Atmospheric Power Production Pollution Study (MAP3S), which was operated by the Department of Energy and NOAA. MAP3S measured wet deposition and estimated dry deposition (later discontinued) for the same analytes. AIRMoN sites collect samples daily when precipitation occurs and are analyzed for the same analytes as NTN samples.

In January 1996, the NADP established the MDN, the third network in the organization. The MDN was formed to provide data on the wet deposition of mercury to surface waters, forested watersheds, and other receptors.

In October 2009, AMNet joined the NADP as its fourth network. AMNet measures the concentration of atmospheric mercury using on-site instrumentation, closing the gap between wet and dry deposition of mercury.

In October 2010, AMoN joined the NADP. Atmospheric ammonia concentrations are measured every two weeks using passive samplers. The AMoN furthers the understanding of wet and dry deposition and ammonia partitioning in the atmosphere, allowing the assessment of ecosystem impacts and secondary air pollution formation.

Beginning in late 2017 and completed in mid-2018, the NADP PO and CAL moved from the University of Illinois at Urbana-Champaign to the University of Wisconsin–Madison. NADP networks continue to support the NADP mission of data quality, outreach, and scientific improvement.



Global distribution and longevity of NADP sites.

About the Maps

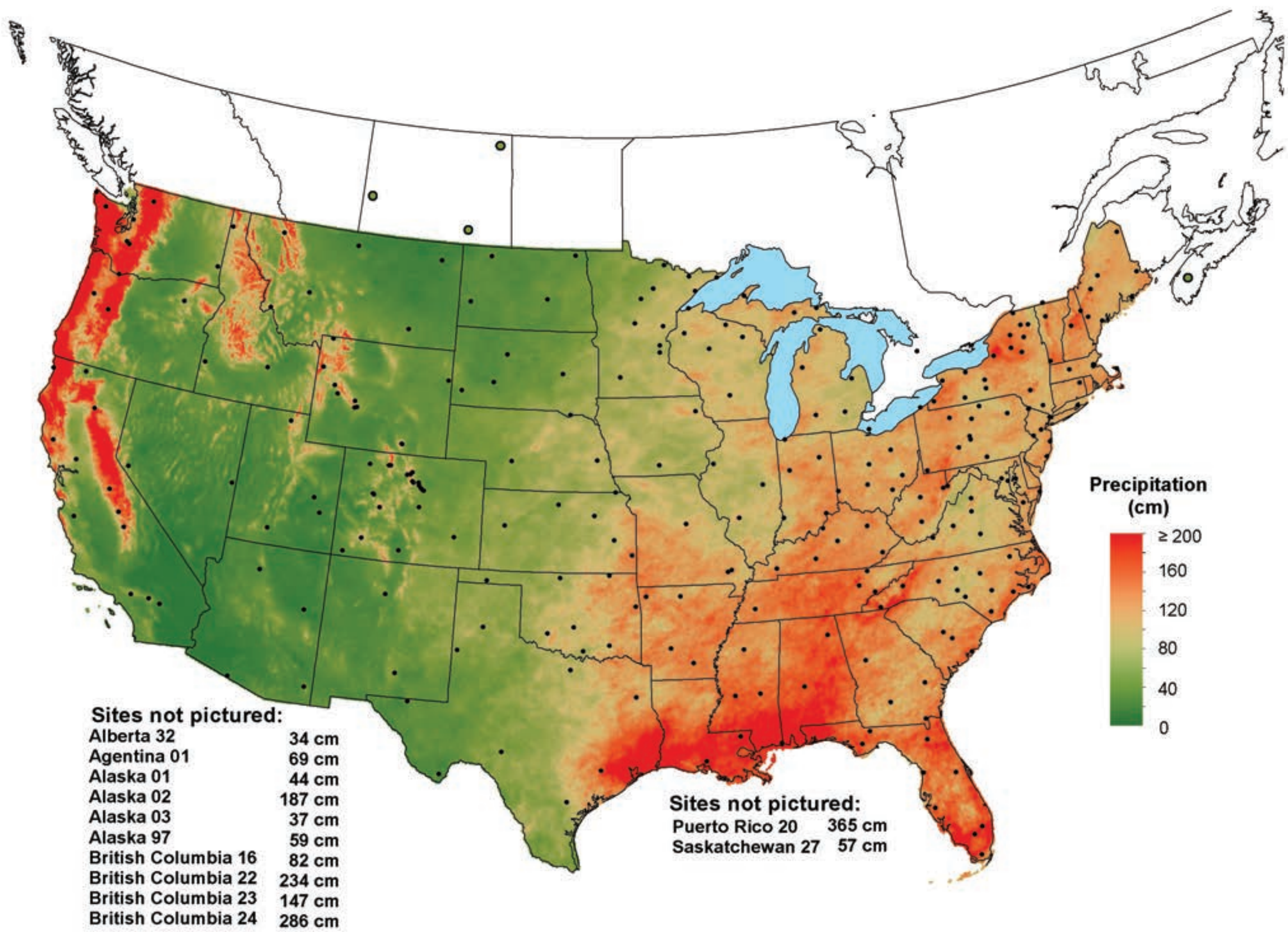
This map series is a principal product of the NADP. It summarizes the results of network operation for the most recent complete calendar year in graphic form. Additional maps, related geographic information, and reviewed analytical results are available on the NADP website.

All map products are restricted to sites that meet completeness criteria (see the NADP website for details). Black dots mark site locations that met NADP completeness criteria in 2017. Open circles designate urban sites, defined as having at least 400 people per square kilometer (km^2) within a 15-km radius of the site. Sites (e.g., Canadian sites) that are too far removed from other observations to extend the contour surface are represented as color-filled circles.

The map contour surface represents a gridded interpolation. Grid points within 500 km of each site are used in computations. Urban sites do not contribute to the contour surface. Colors represent interpolated values of concentration, deposition, or precipitation. The precipitation surface is a modified version of the U.S. precipitation grid developed by the PRISM Climate Group ("Parameter-elevation Regressions on Independent Slopes Model," http:// prism.oregonstate.edu, data downloaded September, 2018). These annual precipitation estimates incorporate point data, a digital elevation model, and expert knowledge of complex climatic extremes to produce continuous grid estimates.

NADP precipitation observations are used to supplement the PRISM precipitation grids through an inverse distance weighting within a 20 km radius of each NADP site (see the NADP website for specific information). PRISM precipitation data are strictly for the continental U.S., so the precipitation gradient north of the U.S./Canadian border is based solely on NADP precipitation data. The resulting precipitation map is used to generate the deposition maps.

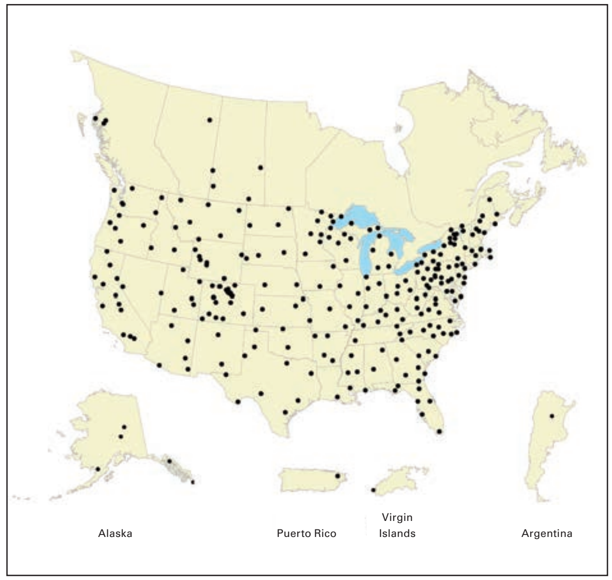
The precipitation figure on the facing page has a continuous gradient of color from dark green (0 cm of precipitation) to yellow to dark red (greater than 200 cm of precipitation). Concentration and deposition maps follow this same format, with specified units on each map. All maps back to 1985 follow this schema and are available in this format from the NADP website (http://nadp.slh.wisc.edu).



Total annual precipitation for 2017, using precipitation measurements from the NADP and PRISM (in cm).

National Trends Network (NTN)

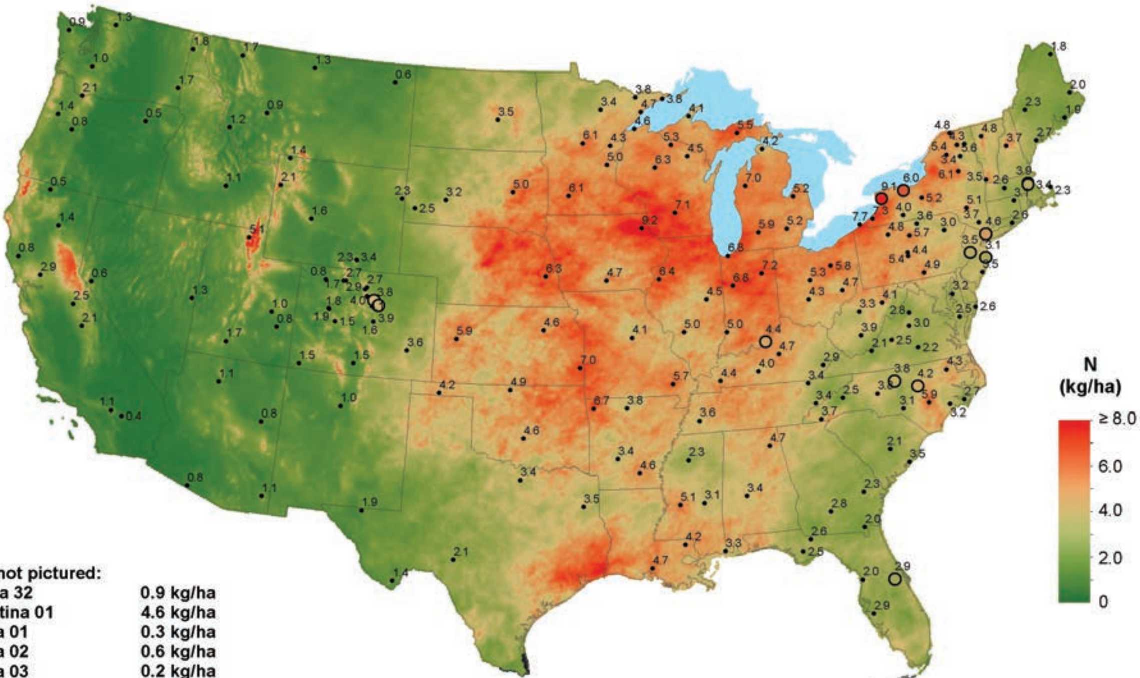
The NTN is the largest North American network that provides a long-term record of precipitation chemistry. Most sites are located away from urban areas and point sources of pollution, although urban sites participate. Each site has a precipitation collector and rain gage. The automated collector ensures sampling only during precipitation (wet-only sampling). Site operators follow standard operating procedures to help ensure NTN data comparability and representativeness across the network. Weekly samples are collected each Tuesday morning, using containers provided by the CAL. All samples are sent to the CAL for analysis of free acidity (H as pH), specific conductance, calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), sulfate (SO_4), nitrate (NO_3), chloride (Cl), bromide (Br), and ammonium (NH_4) ions. The CAL analyzes inorganic orthophosphate ions (PO_4) for quality assurance purposes and possible contamination. The CAL reviews field and laboratory data for accuracy and completeness and flags samples that were mishandled, compromised by equipment failure, or grossly contaminated. Data from the NTN are available on the NADP website (http://nadp.slh.wisc.edu/ntn/).



NTN Maps

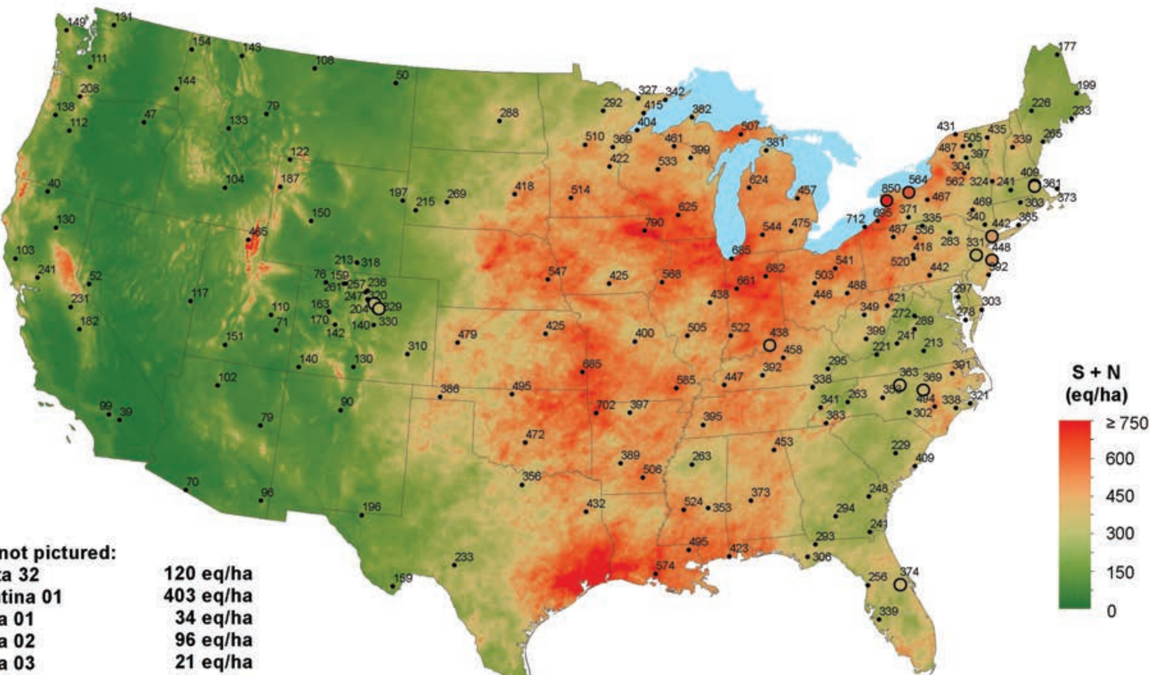
The maps on pages 13 through 21 show precipitation-weighted mean concentration and annual wet deposition for select acidic ions, nutrients, and base cations. Spatial variability in these species can be seen both on regional and national scales. In 2017, 211 of the 264 active sites met NADP completeness criteria. Concentration and deposition maps are included for SO_4, NO_3, NH_4, pH, Ca, Mg, Cl, and Na. Maps of Br and K are not included in this report, but are available from the NADP website.

Annual maps for wet deposition of inorganic nitrogen (i.e., $NO_3 + NH_4$) and nitrogen + sulfur (N + S) are also included. N + S (i.e., $NO_3 + NH_4 + SO_4$) deposition is mapped as hydrogen ion equivalents per hectare (eq/ha).



Sites not pictured:

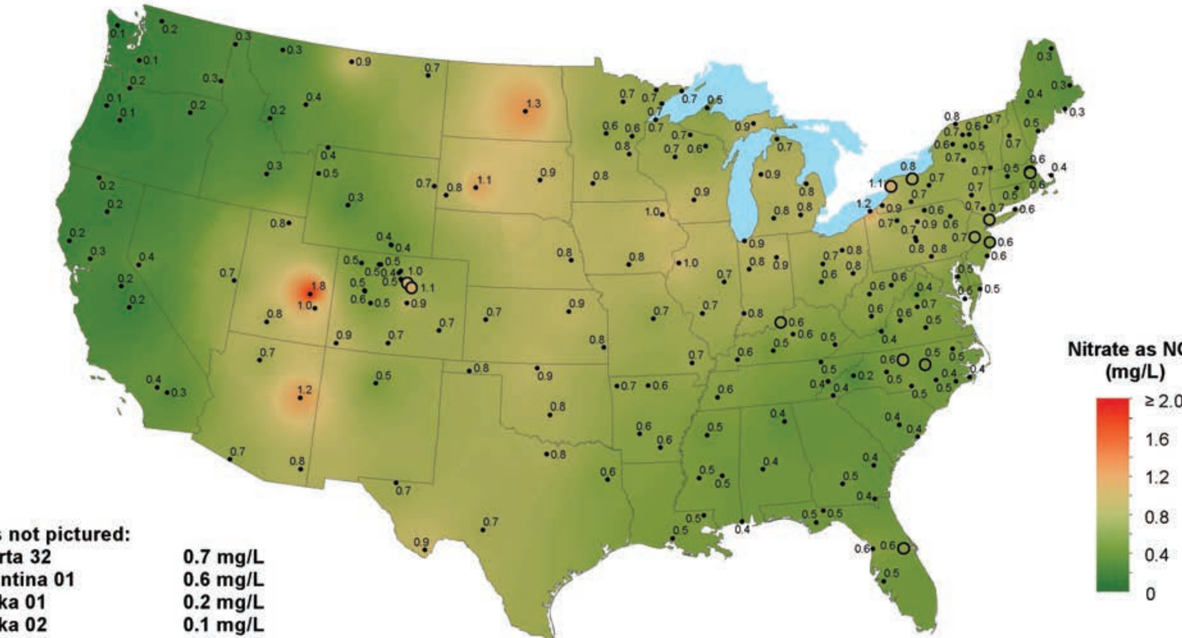
Alberta 32	0.9 kg/ha
Argentina 01	4.6 kg/ha
Alaska 01	0.3 kg/ha
Alaska 02	0.6 kg/ha
Alaska 03	0.2 kg/ha
Alaska 97	0.3 kg/ha
British Columbia 22	0.9 kg/ha
British Columbia 23	0.4 kg/ha
British Columbia 24	1.0 kg/ha
Saskatchewan 21	2.0 kg/ha
Saskatchewan 31	1.8 kg/ha



Sites not pictured:

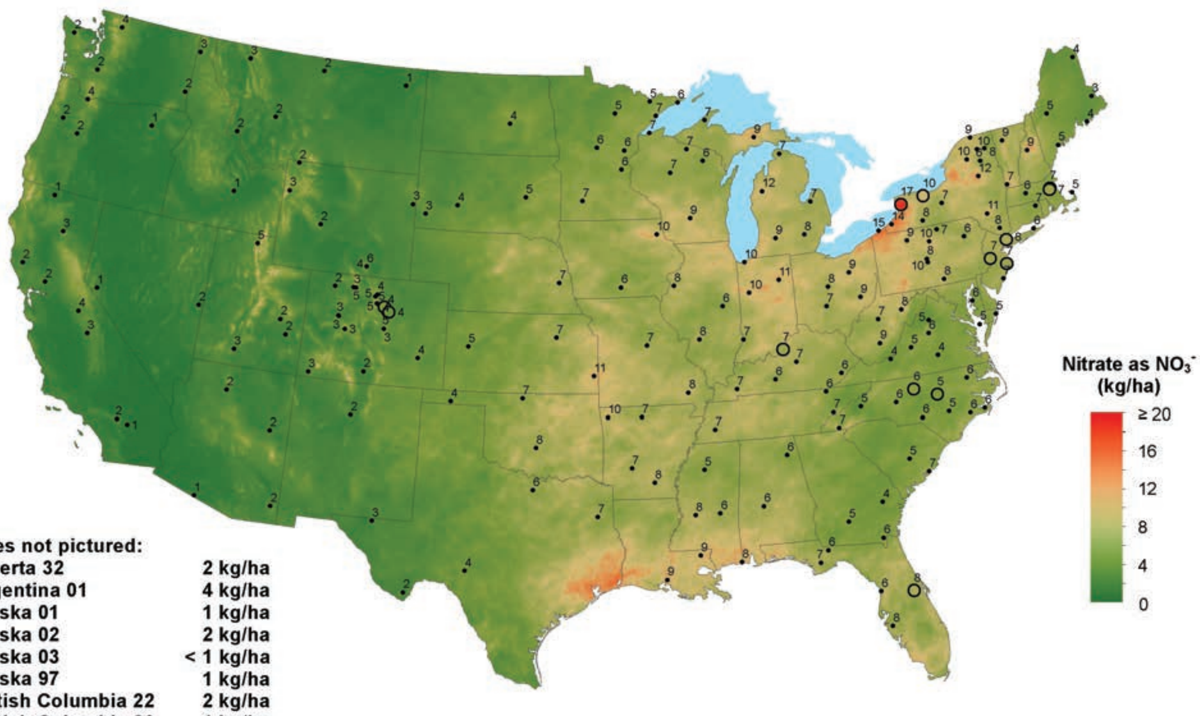
Alberta 32	120 eq/ha
Argentina 01	403 eq/ha
Alaska 01	34 eq/ha
Alaska 02	96 eq/ha
Alaska 03	21 eq/ha
Alaska 97	60 eq/ha
British Columbia 22	777 eq/ha
British Columbia 23	111 eq/ha
British Columbia 24	186 eq/ha
Saskatchewan 21	169 eq/ha
Saskatchewan 31	153 eq/ha

Inorganic nitrogen wet deposition from nitrate and ammonium (top) and nitrogen plus sulfur wet deposition from nitrate, ammonium, and sulfate (bottom), 2017.



Sites not pictured:

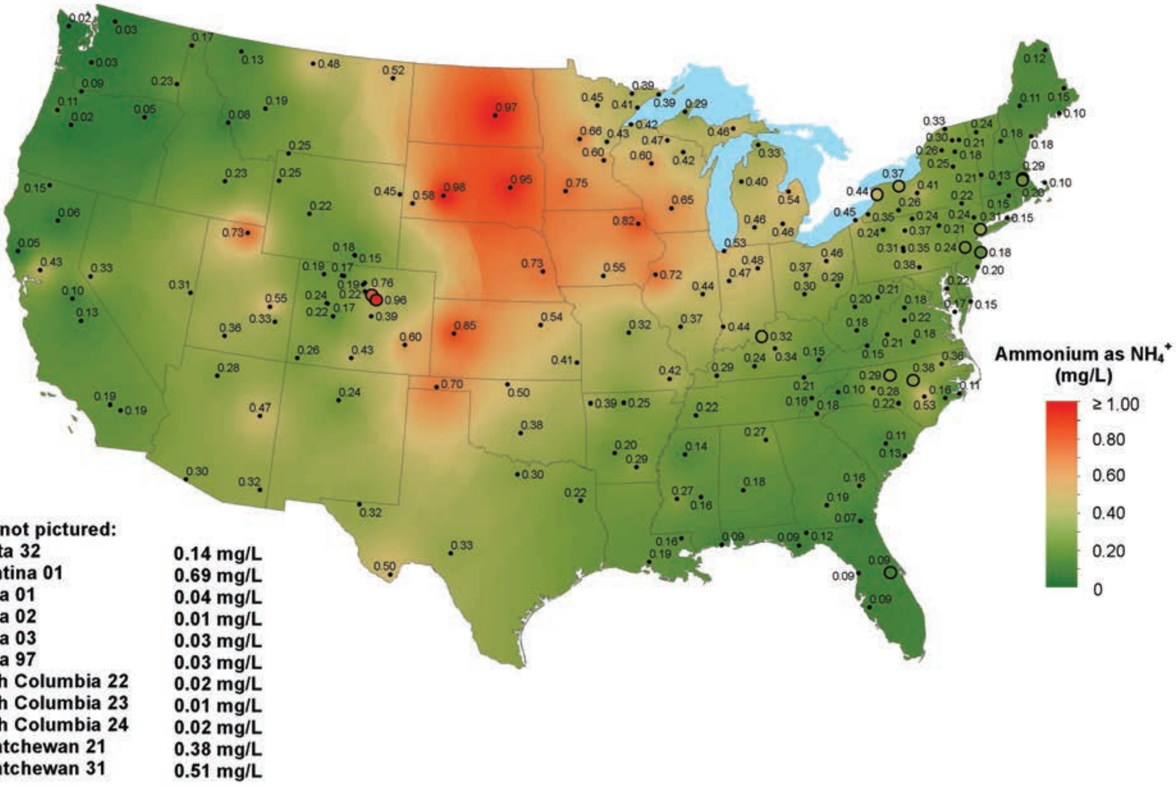
Alberta 32	0.7 mg/L
Argentina 01	0.6 mg/L
Alaska 01	0.2 mg/L
Alaska 02	0.1 mg/L
Alaska 03	0.1 mg/L
Alaska 97	0.1 mg/L
British Columbia 22	0.1 mg/L
British Columbia 23	0.1 mg/L
British Columbia 24	0.1 mg/L
Saskatchewan 21	0.5 mg/L
Saskatchewan 31	0.8 mg/L

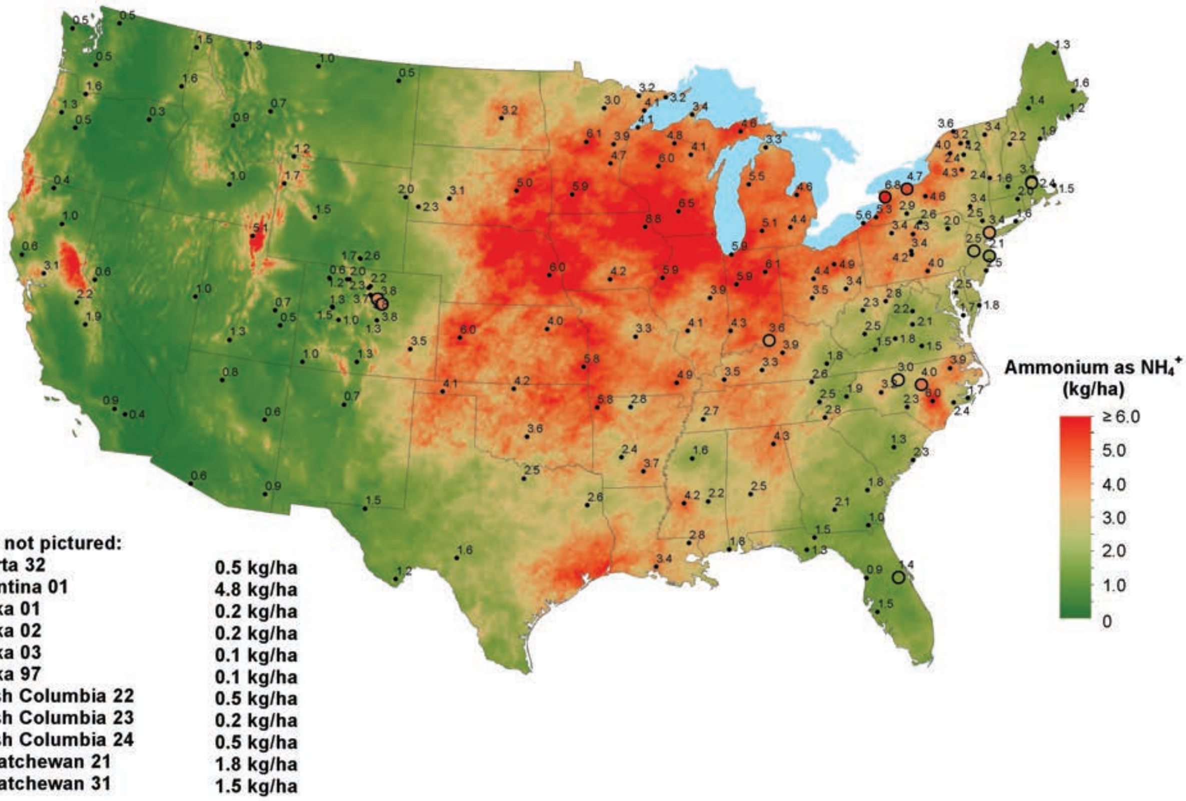


Sites not pictured:

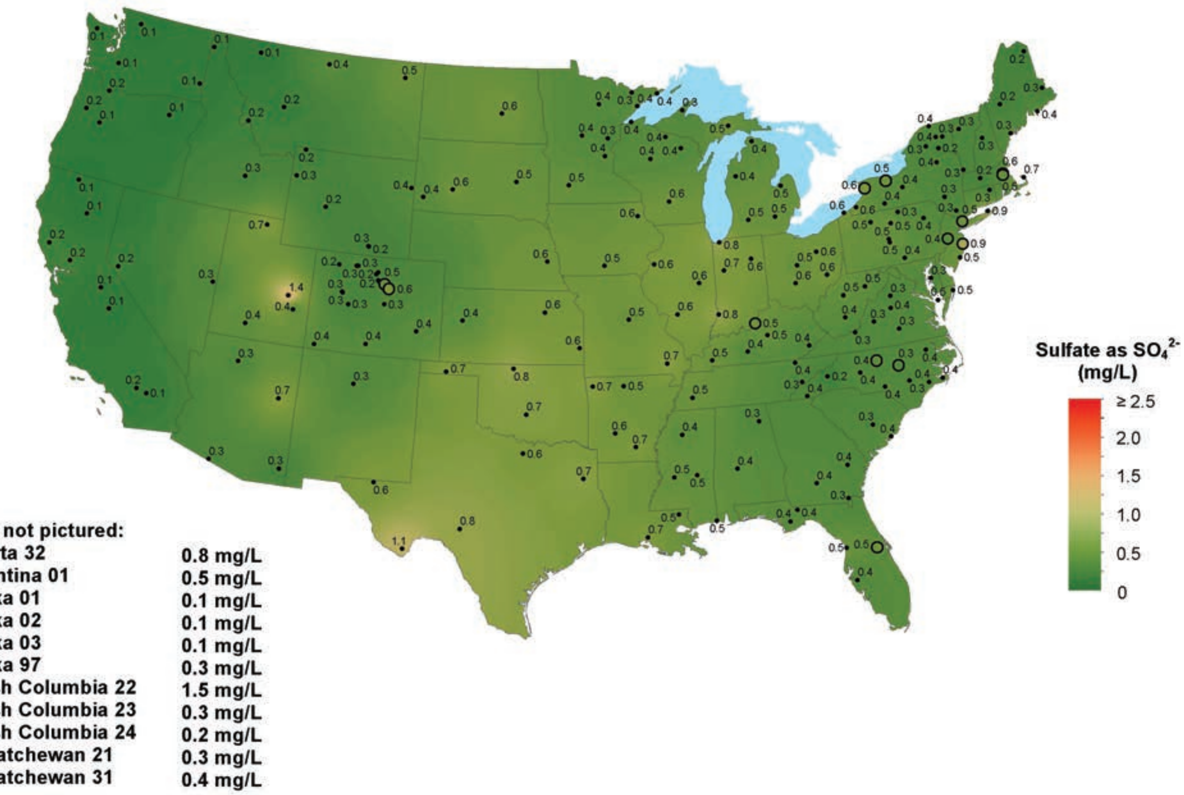
Alberta 32	2 kg/ha
Argentina 01	4 kg/ha
Alaska 01	1 kg/ha
Alaska 02	2 kg/ha
Alaska 03	< 1 kg/ha
Alaska 97	1 kg/ha
British Columbia 22	2 kg/ha
British Columbia 23	1 kg/ha
British Columbia 24	3 kg/ha
Saskatchewan 21	3 kg/ha
Saskatchewan 31	2 kg/ha

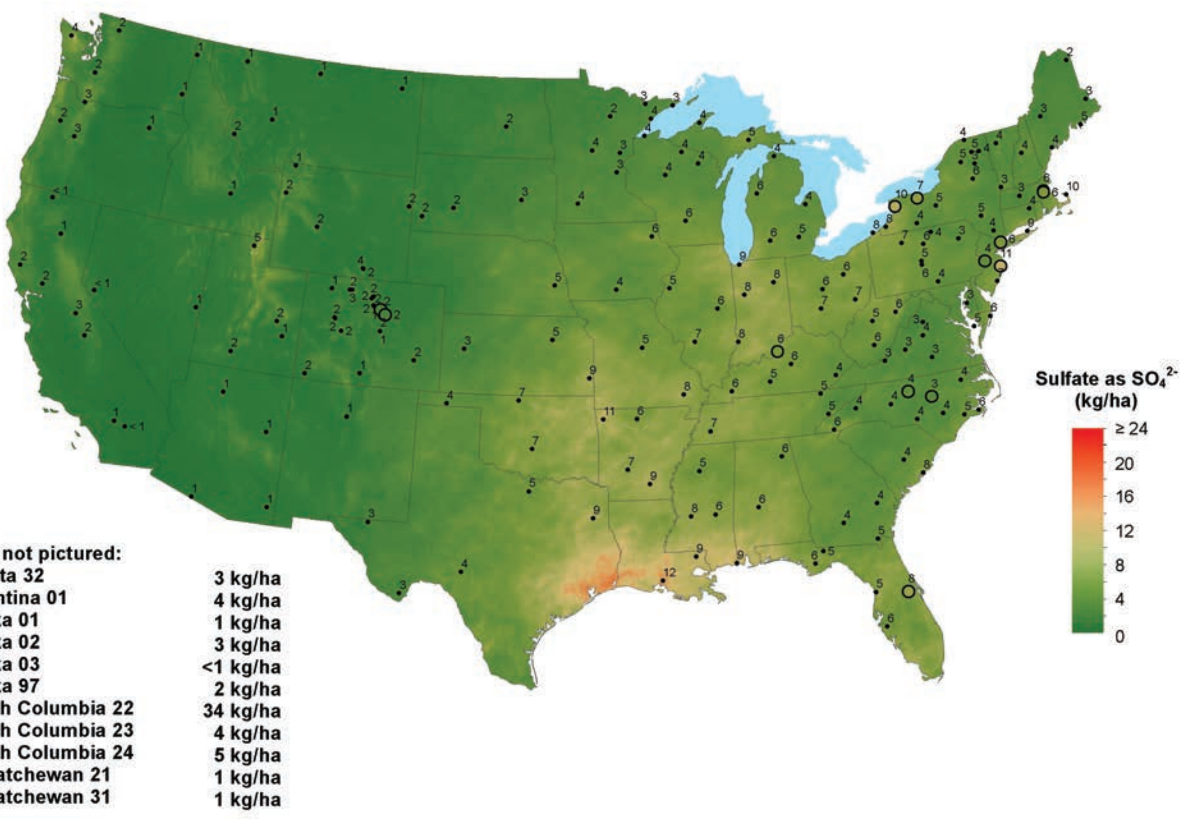
Nitrate ion concentration (top) and wet deposition (bottom), 2017.



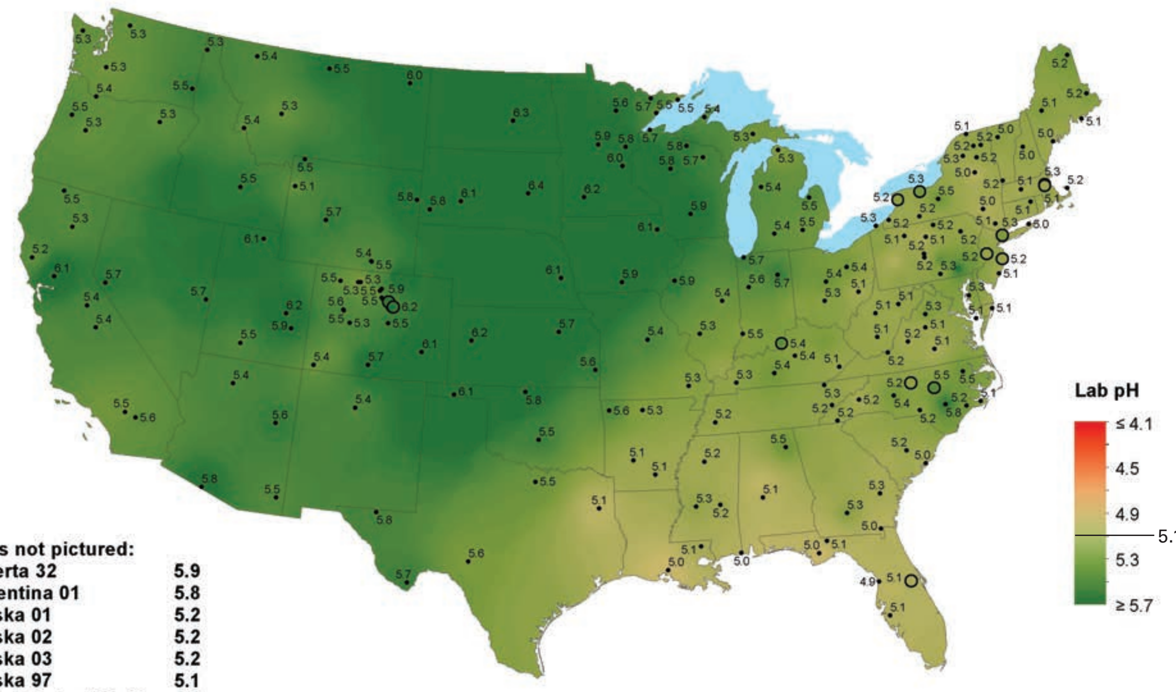


Ammonium ion concentration (top) and wet deposition (bottom), 2017.



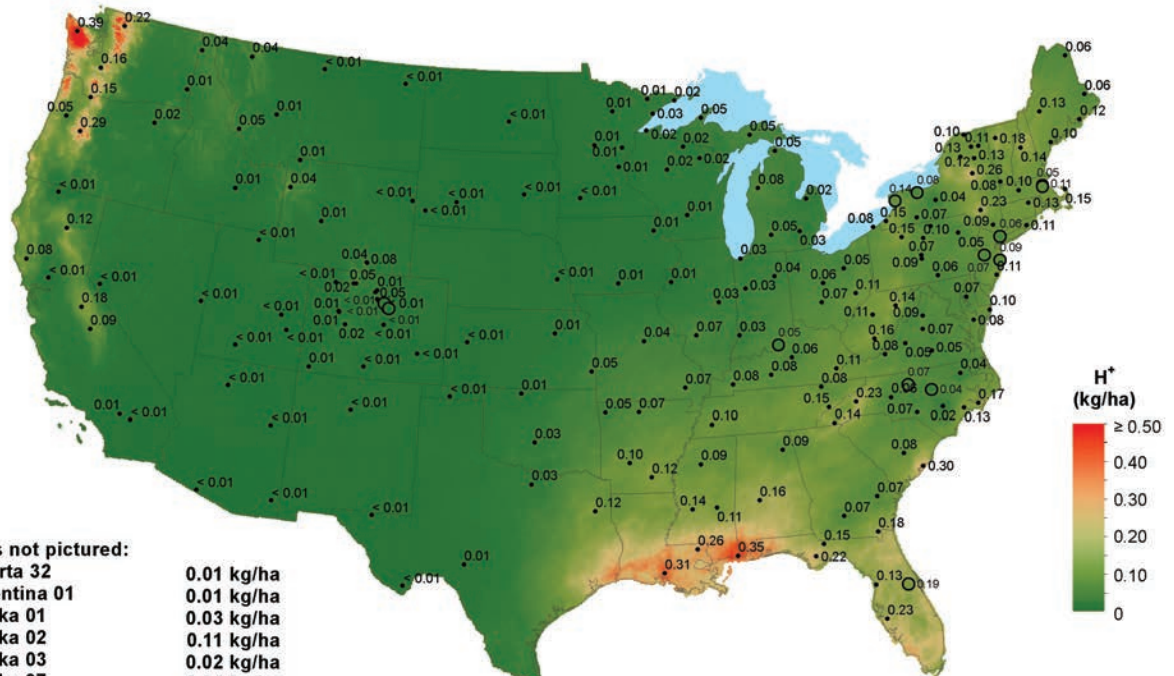


Sulfate ion concentration (top) and wet deposition (bottom), 2017.



Sites not pictured:

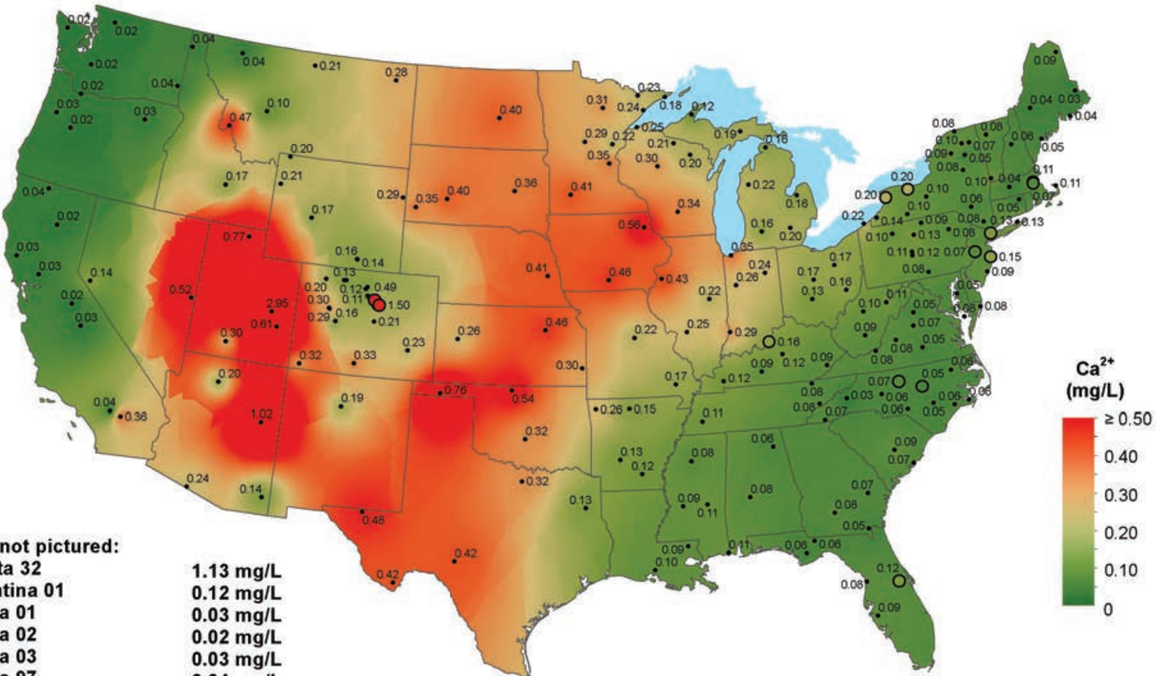
Alberta 32	5.9
Argentina 01	5.8
Alaska 01	5.2
Alaska 02	5.2
Alaska 03	5.2
Alaska 97	5.1
British Columbia 22	4.4
British Columbia 23	5.0
British Columbia 24	5.2
Saskatchewan 21	5.7
Saskatchewan 31	5.8



Sites not pictured:

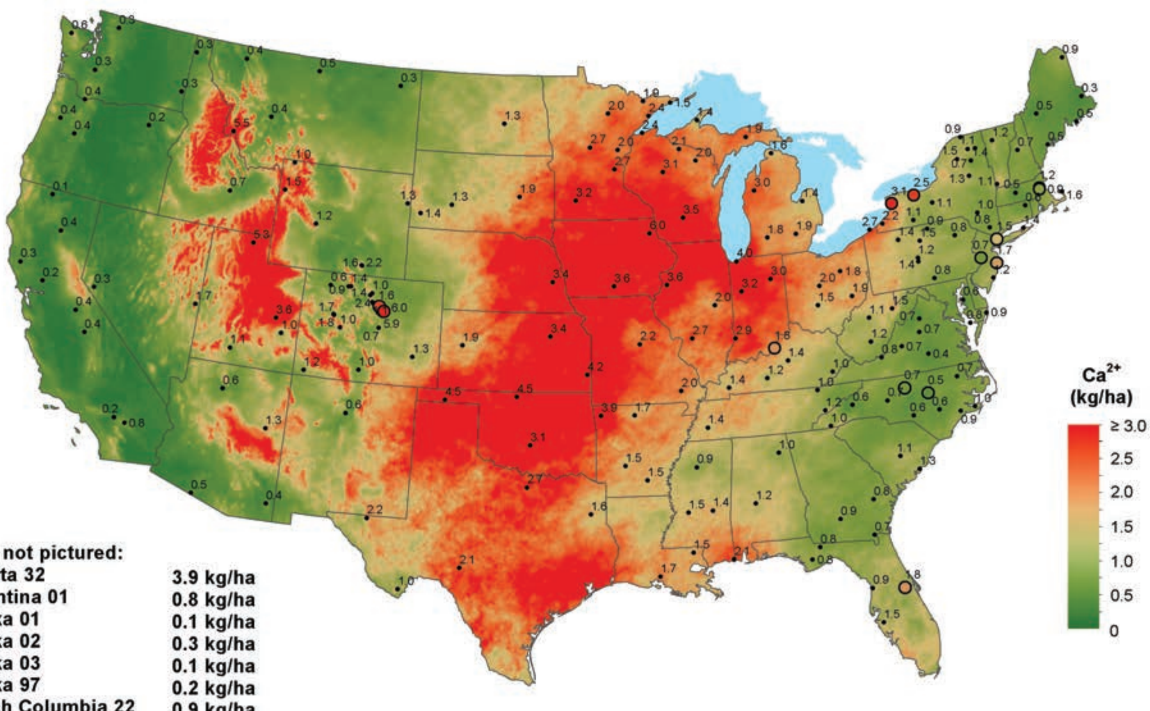
Alberta 32	0.01 kg/ha
Argentina 01	0.01 kg/ha
Alaska 01	0.03 kg/ha
Alaska 02	0.11 kg/ha
Alaska 03	0.02 kg/ha
Alaska 97	0.04 kg/ha
British Columbia 22	0.89 kg/ha
British Columbia 23	0.13 kg/ha
British Columbia 24	0.17 kg/ha
Saskatchewan 21	0.01 kg/ha
Saskatchewan 31	0.01 kg/ha

Hydrogen ion concentration as pH (top) and wet deposition (bottom), 2017. Typically, a precipitation pH of less than 5.1 is considered acidic.



Sites not pictured:

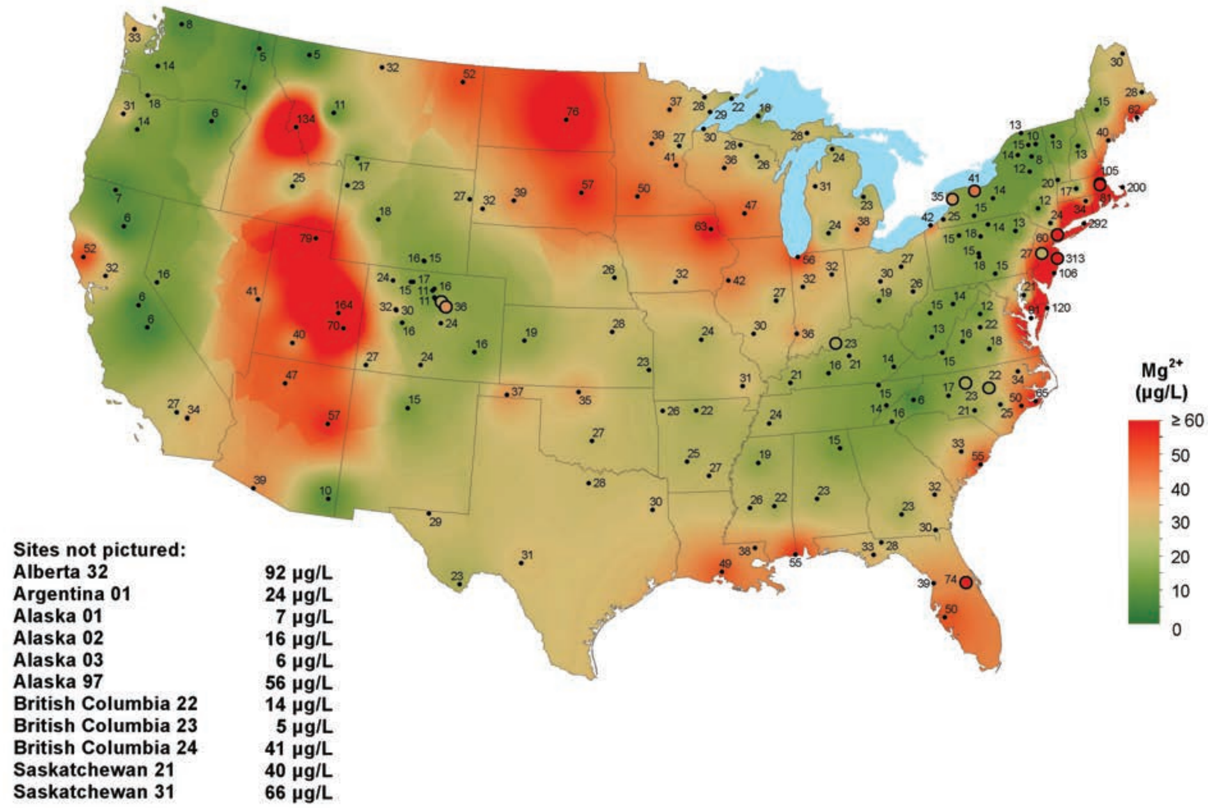
Alberta 32	1.13 mg/L
Argentina 01	0.12 mg/L
Alaska 01	0.03 mg/L
Alaska 02	0.02 mg/L
Alaska 03	0.03 mg/L
Alaska 97	0.04 mg/L
British Columbia 22	0.04 mg/L
British Columbia 23	0.02 mg/L
British Columbia 24	0.03 mg/L
Saskatchewan 21	0.17 mg/L
Saskatchewan 31	0.29 mg/L

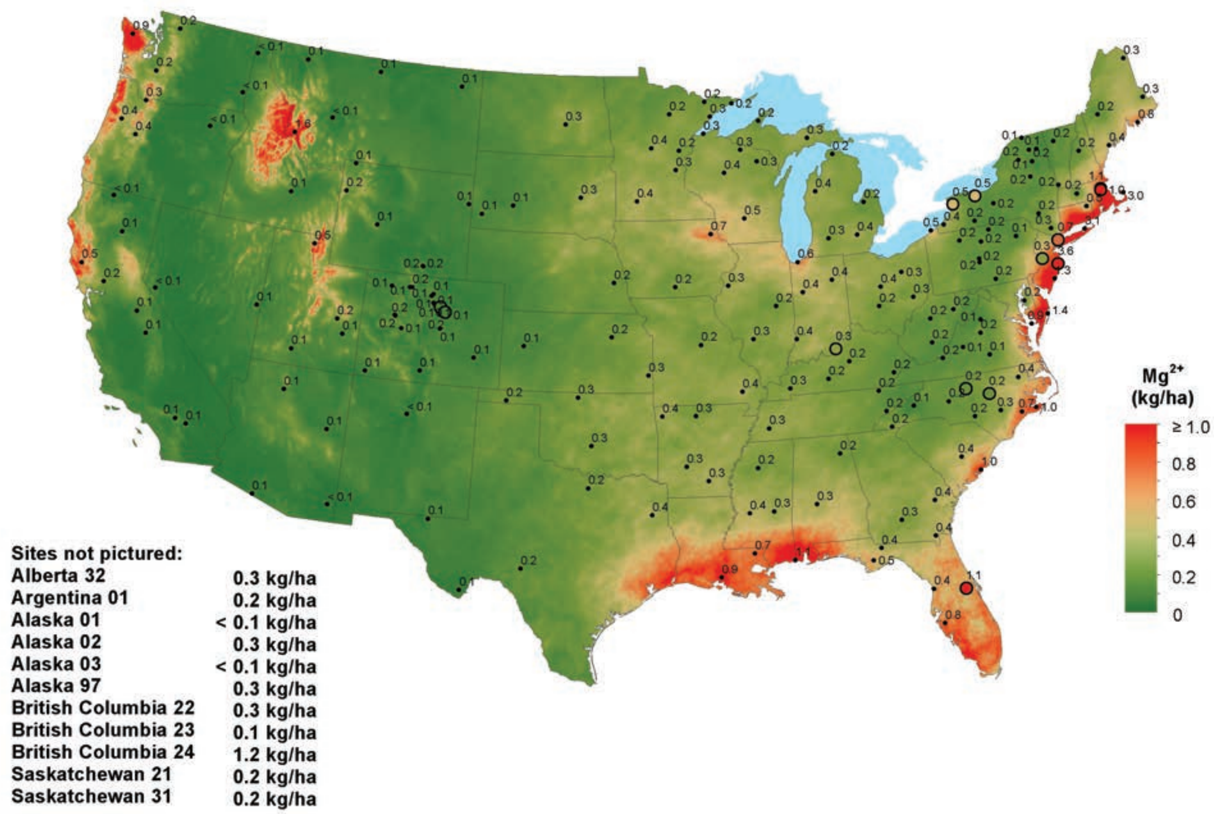


Sites not pictured:

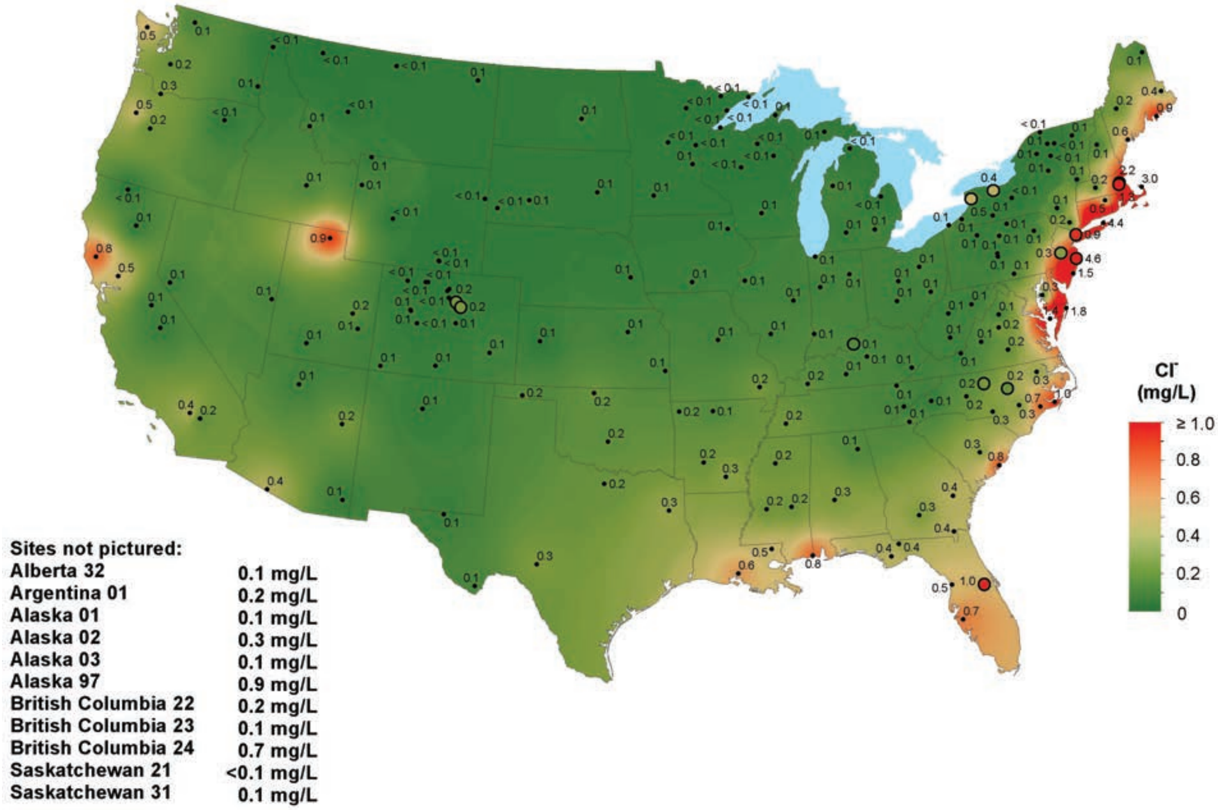
Alberta 32	3.9 kg/ha
Argentina 01	0.8 kg/ha
Alaska 01	0.1 kg/ha
Alaska 02	0.3 kg/ha
Alaska 03	0.1 kg/ha
Alaska 97	0.2 kg/ha
British Columbia 22	0.9 kg/ha
British Columbia 23	0.2 kg/ha
British Columbia 24	0.7 kg/ha
Saskatchewan 21	0.8 kg/ha
Saskatchewan 31	0.9 kg/ha

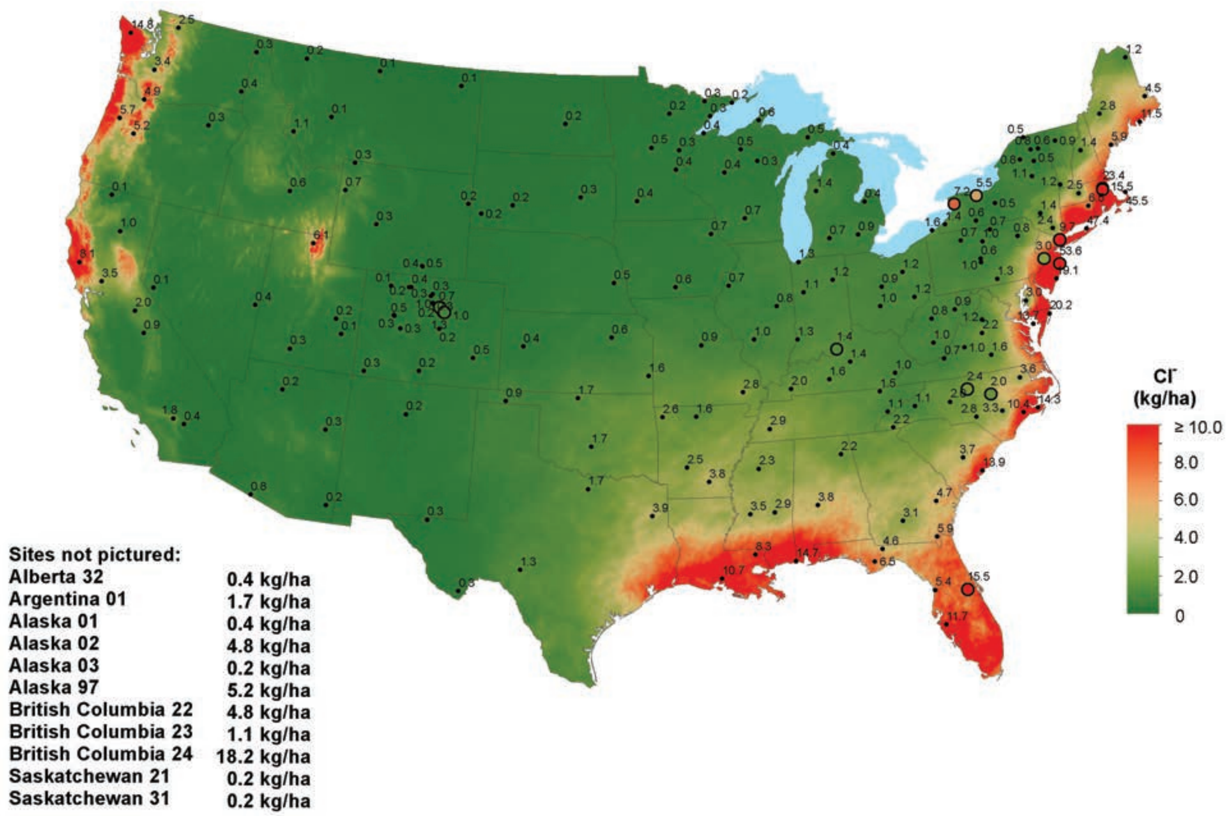
Calcium ion concentration (top) and wet deposition (bottom), 2017.



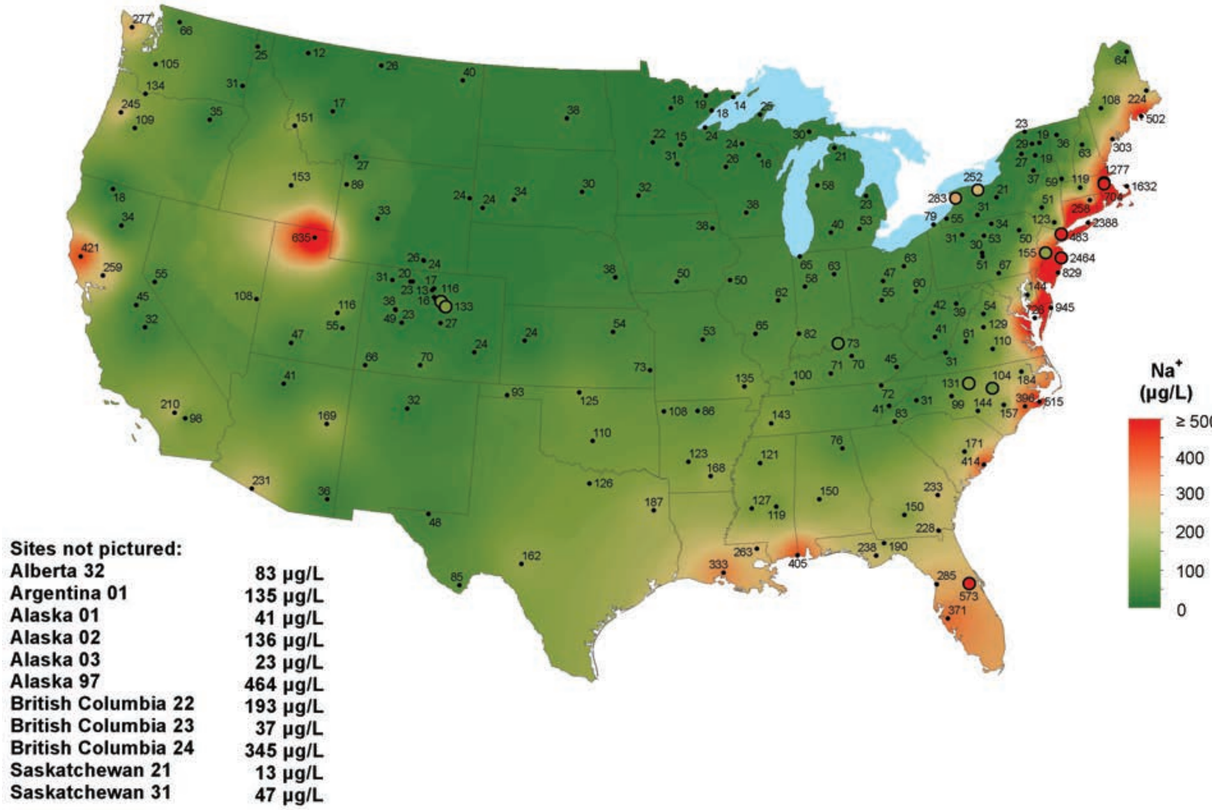


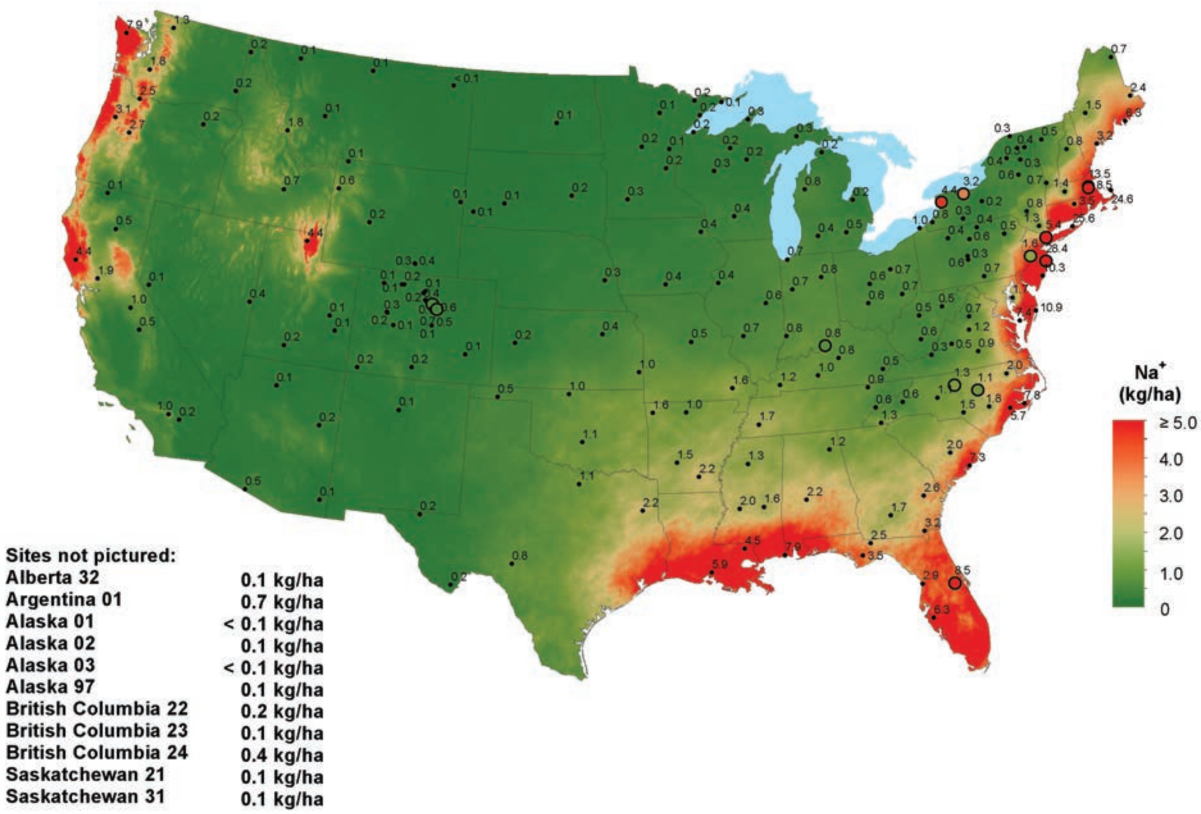
Magnesium ion concentration (top) and wet deposition (bottom), 2017.





Chloride ion concentration (top) and wet deposition (bottom), 2017.





Sodium ion concentration (top) and wet deposition (bottom), 2017.

Atmospheric Integrated Research Monitoring Network (AIRMoN)

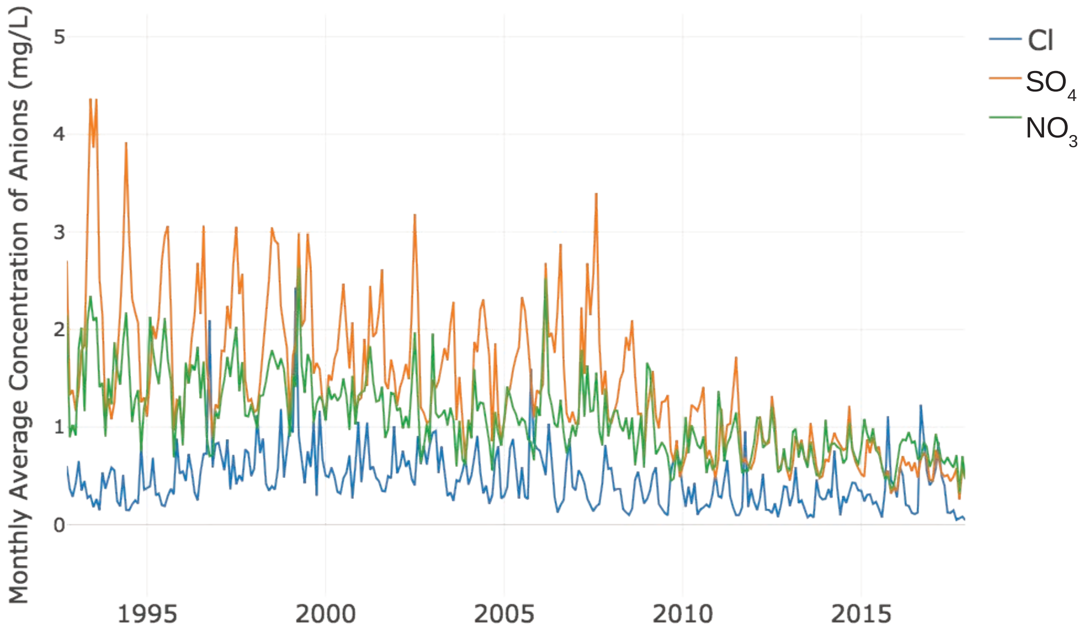
AIRMoN samples are collected daily within 24 hours of the start of precipitation, often providing data for individual storm events. Event-based data facilitate studies of atmospheric processes, give insight to wet deposition data quality sensitivity, and support the development and testing of atmospheric models, such as the NOAA/HYSPLIT fate and transport model and Community Multiscale Air Quality (CMAQ) Modeling System.

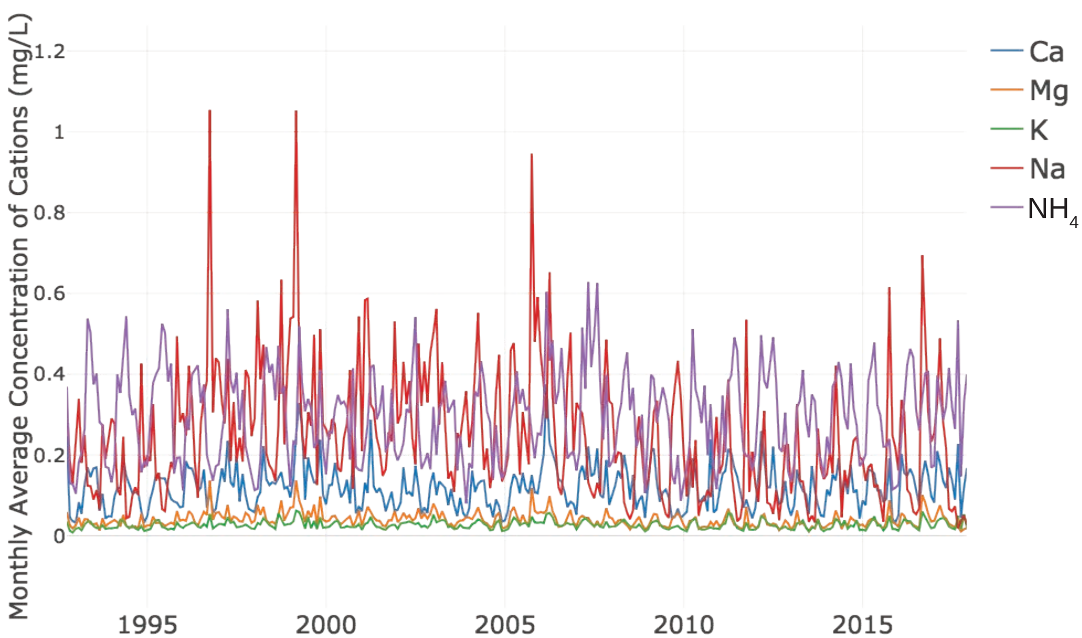
AIRMoN sites are equipped with the same wet-only deposition collector used at NTN sites. All AIRMoN sites operate digital rain gages to report total precipitation. Each site also has a standard stick-type precipitation gage as a backup.

Samples are refrigerated after collection and are shipped in chilled, insulated containers to the CAL for analysis. Samples remain refrigerated until they are analyzed. Refrigeration helps retard potential chemical changes, such as reactivity and partitioning of H, NH_4, and PO_4. Chemical analyses and data screening procedures for AIRMoN and NTN are similar. Data from the AIRMoN are available on the NADP website (http://nadp.slh.wisc.edu/AIRMoN/).

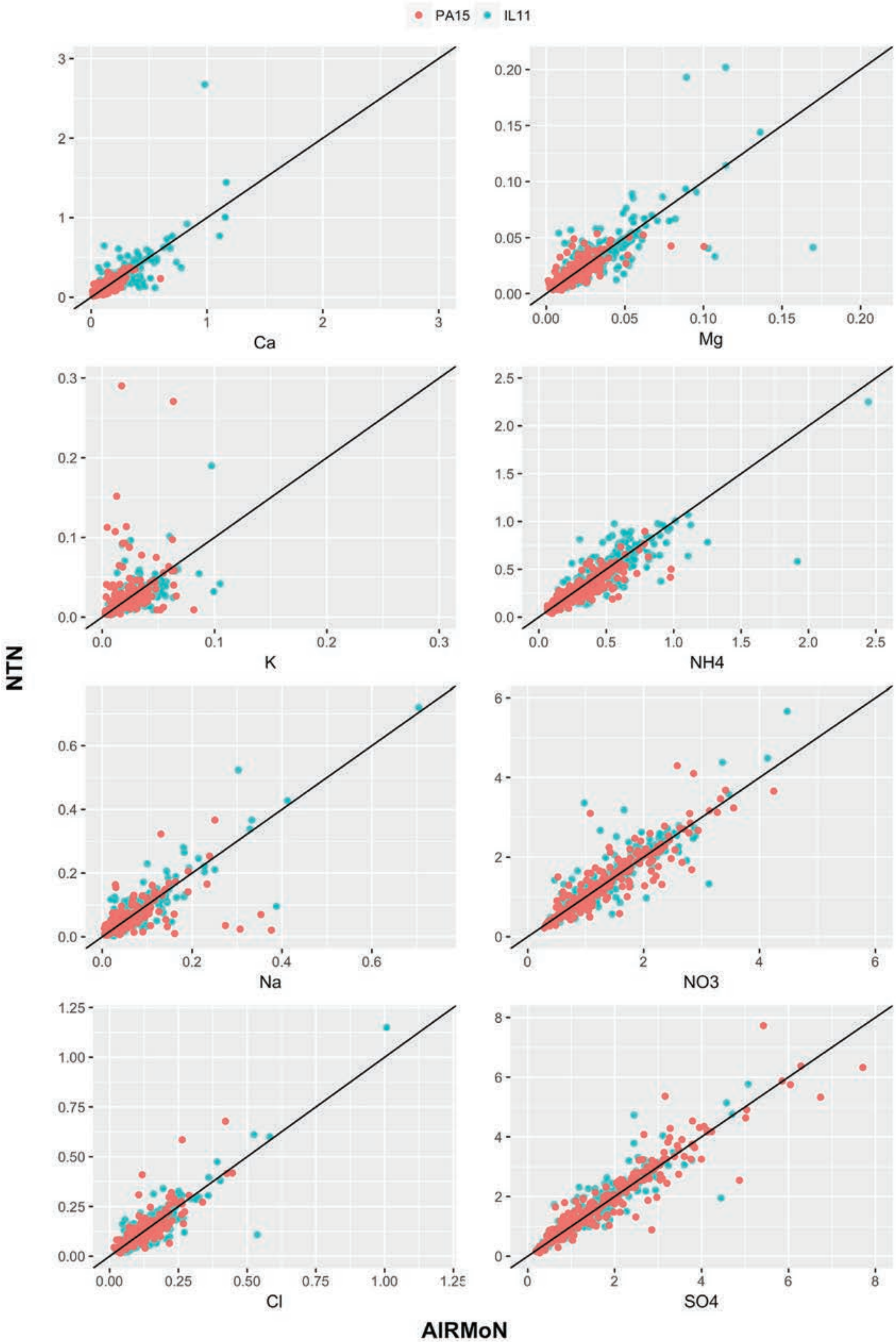
The AIRMoN network offers a unique set of data, with a significant increase in temporal resolution compared to the NTN. The following figures show the important long term trends observed since the AIRMoN began operation in 1992. In particular, the strong trend of reduced SO_4 and NO_3 concentrations in precipitation can be seen. Two sites - IL11 and PA15 - have been continuously active since 1992 through 2017 and are collocated with NTN sites.

As a method of assessing the results from the AIRMoN sites, a comparison of monthly weighted averages of major ions is plotted against NTN results. The plots show strong agreement between the two independent networks, but the temporal resolution available from AIRMoN is lost. Finally, the monthly weighted average of major ionic species for active AIRMoN sites are shown, indicating the seasonal trends at DE02, IL11, NY67, PA15, TN00, and WV99. Stacked bar plots show the concentration of major cations in the positive direction, while major anion concentrations are shown in the opposite direction.

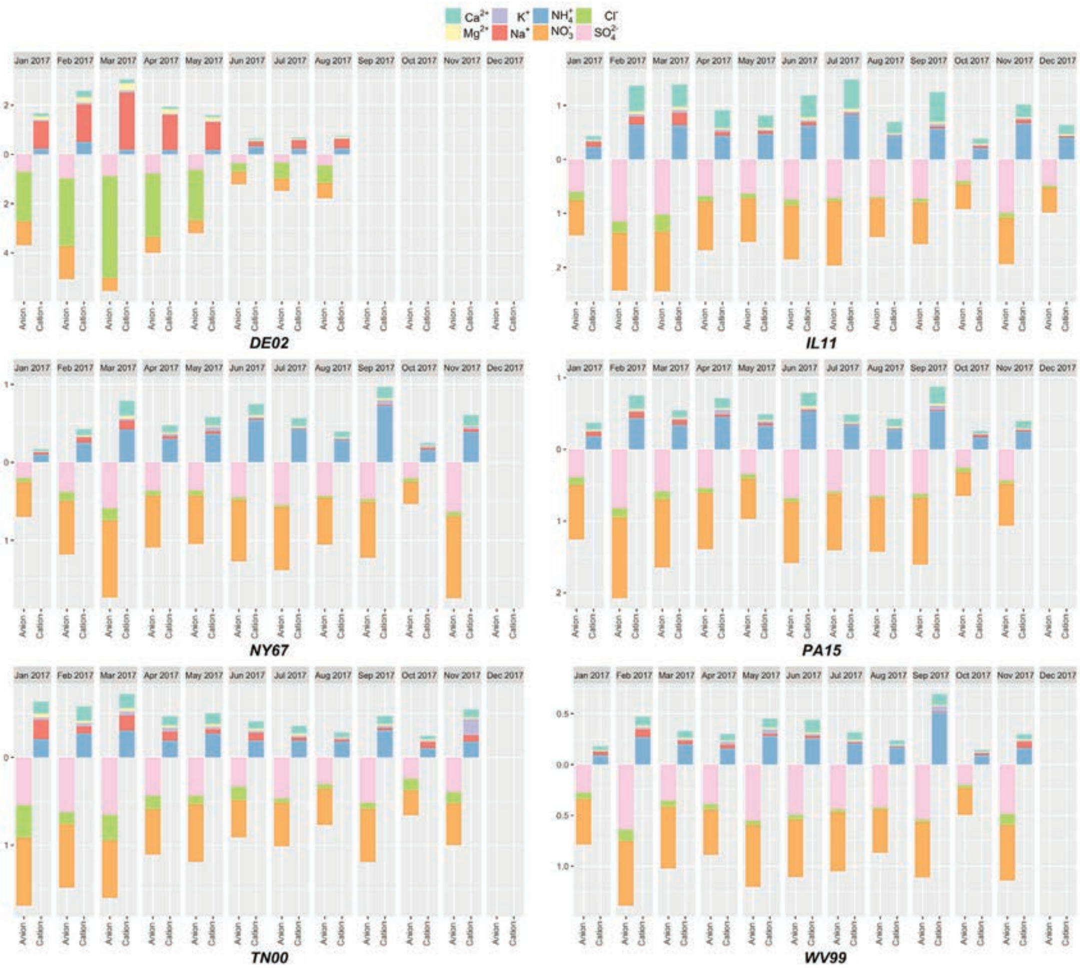




The long term monthly weighted average for all AIRMoN sites since 1992. The results show a strong trend in the reduction of major anions across the network.



For data collected from 1992 through 2017 - A comparison of NTN and AIRMoN weighted monthly averages at two of the longest running AIRMoN sites (IL11 and PA15) with co-located NTN samplers. The results (in mg/L) show strong agreement between the two independent networks.



Time series of 2017 monthly weighted average cation and anion concentrations (mg/L) at the AIRMoN sites.

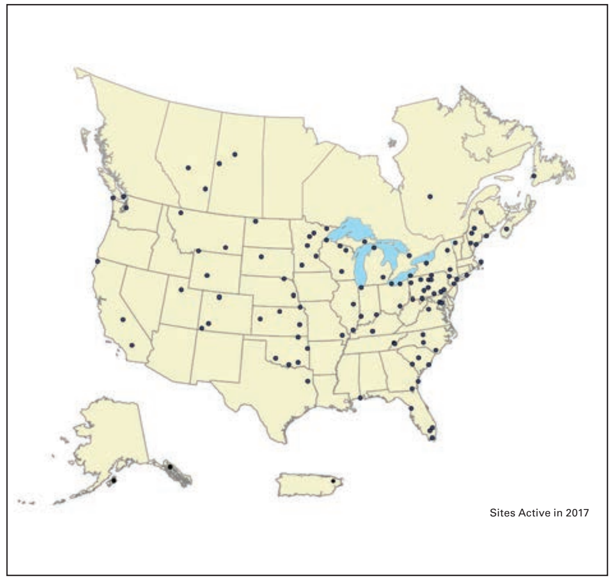
Mercury Deposition Network (MDN)

The MDN is the only network providing a long-term record for the concentration of mercury (Hg) in precipitation in North America. MDN sites follow standard procedures and use approved precipitation collectors and rain gages. The automated collector is similar to the NTN collector, but it is modified to preserve mercury. Site operators collect samples every Tuesday morning. Chemical analysis of the MDN samples is performed by the Mercury Analytical Laboratory (HAL) at Eurofins Frontier Global Sciences, Inc., Bothell Washington.

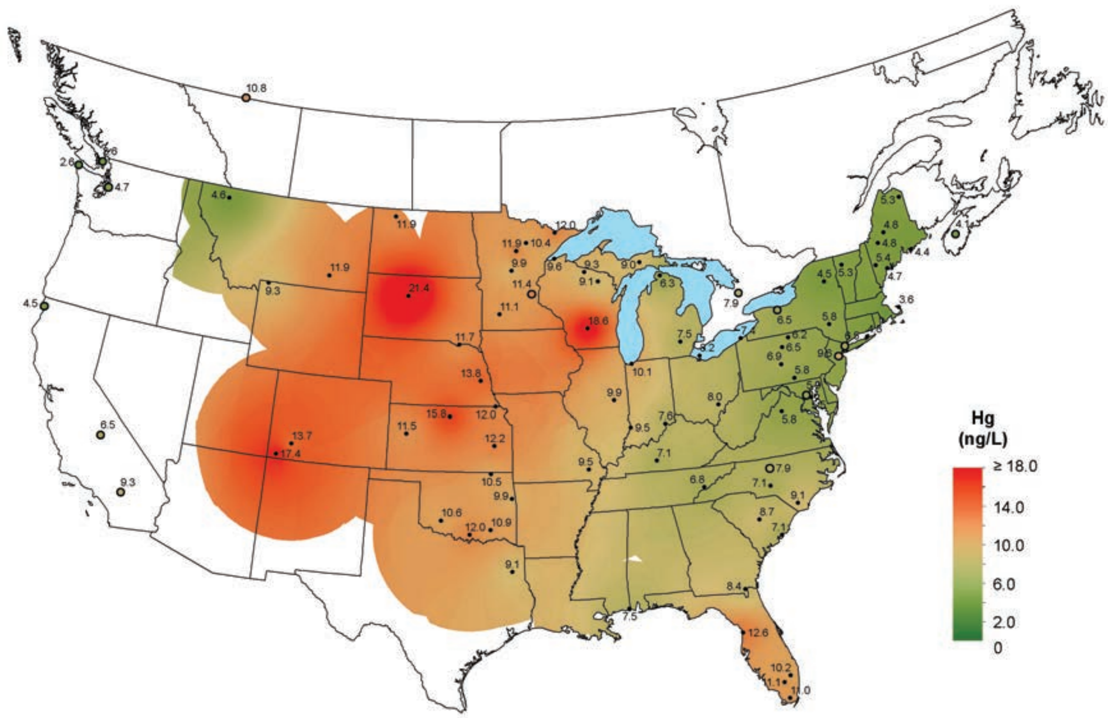
All MDN samples are analyzed for total mercury concentration. The HAL reviews field and laboratory data for accuracy and completeness, and identifies samples that were mishandled, compromised by equipment failure, or grossly contaminated. Data from the MDN are available on the NADP website (http://nadp.slh.wisc.edu/MDN/). Subsamples of MDN precipitation were analyzed for methyl mercury (MeHg) at 11 NADP sites. Details about sample collection and analysis are available on the NADP website.

MDN Maps and Graphs

The maps on page 27 show spatial variability in the precipitation-weighted mean concentration and wet deposition of total mercury across the United States.

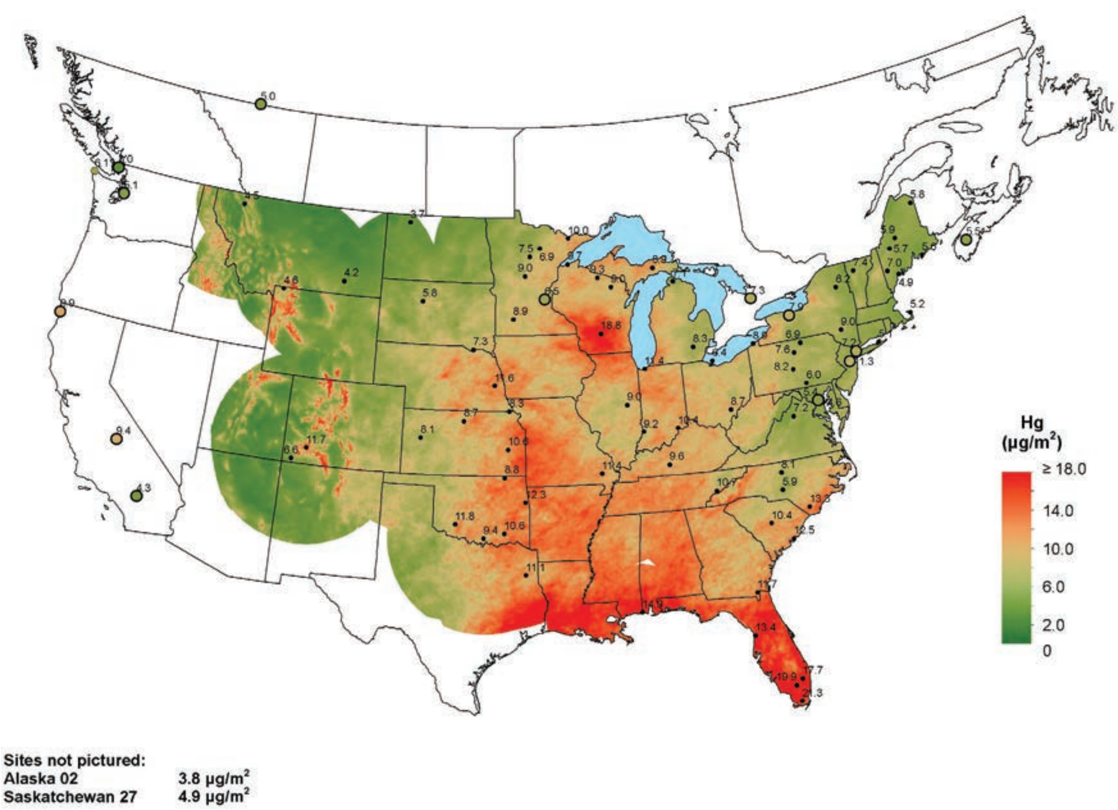


Only sites meeting NADP completeness criteria are included. In 2017, 85 of 99 active sites met these criteria. Spatial variability of total mercury can be seen on regional and national scales.



Sites not pictured:

Alaska 02	**2.1 ng/L**
Saskatchewan 27	**8.6 ng/L**

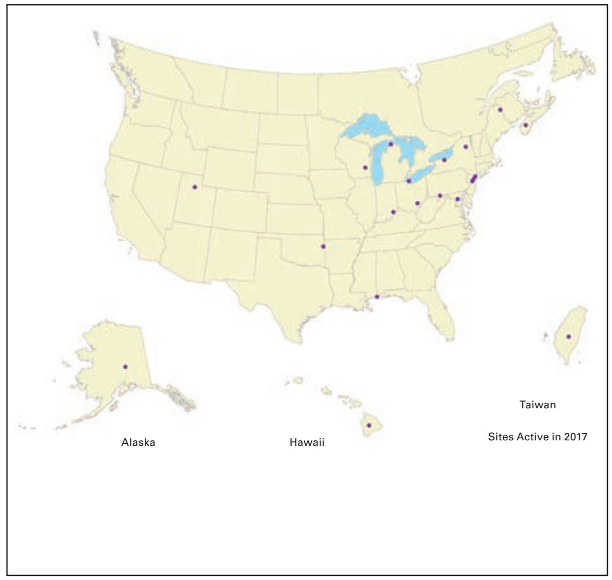


Sites not pictured:

Alaska 02	**3.8 $\mu g/m^2$**
Saskatchewan 27	**4.9 $\mu g/m^2$**

Total mercury concentration (top) and wet deposition (bottom), 2017.

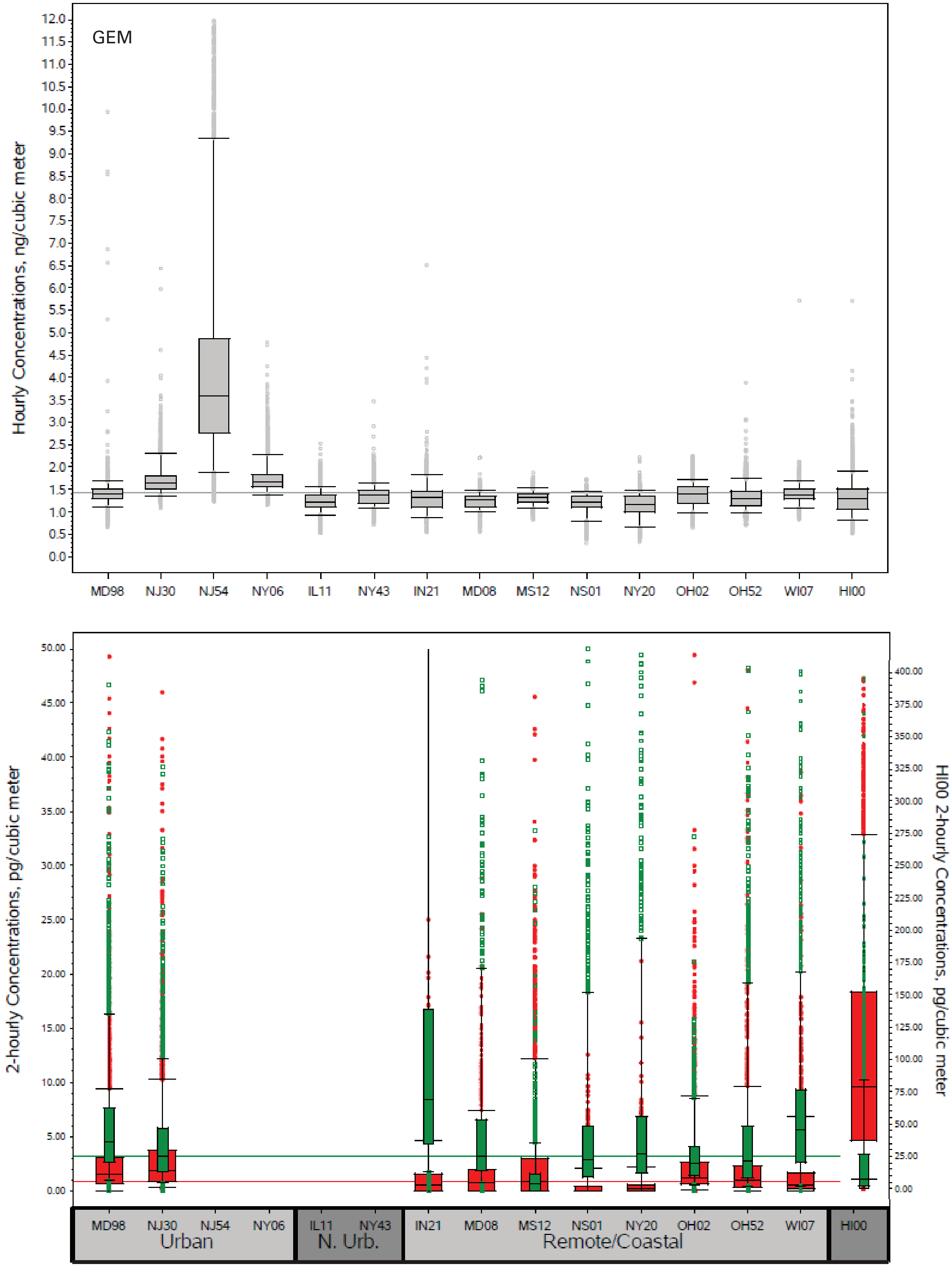
Atmospheric Mercury Network (AMNet)



AMNet sites measure ambient atmospheric mercury using automated, continuous measurement systems in order to understand the impact of atmospheric mercury on deposition. Quality-assured measurements are made using NADP standardized methods.

AMNet measurements are made continuously (five minute and two-hour averages). Data are qualified and averaged to one-hour (gaseous elemental mercury, GEM) and two-hour values (gaseous oxidized mercury, GOM, and particulate bound mercury, $PBM_{2.5}$). As of December 2017, there were 18 AMNet sites. Data from the AMNet are available on the NADP website (http://nadp.slh.wisc.edu/AMNet/).

The figures on page 29 show the distribution of atmospheric mercury concentrations for each site meeting completeness criteria in 2017. The top figure shows the distribution of GEM (shaded grey area) for all sites meeting criteria, in nanograms per cubic meter (ng/m^3). The bottom figure shows the distribution of two-hour atmospheric concentrations of GOM (red shaded area), and $PBM_{2.5}$ (green shaded area) in picograms per cubic meter (pg/m^3).



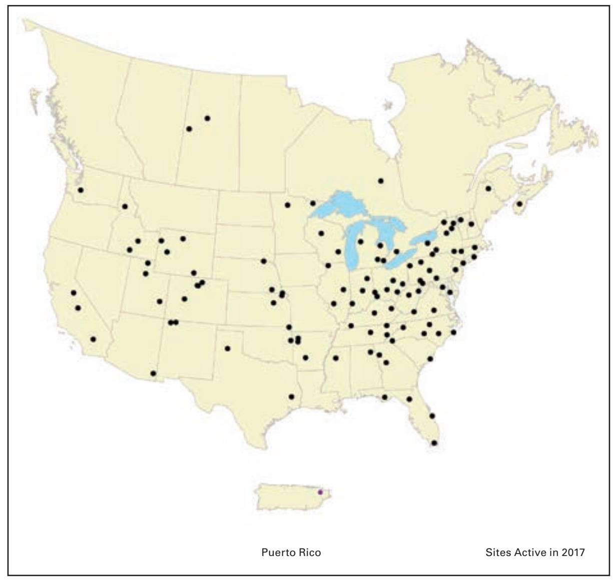
Hourly GEM concentration in ng/m3 for each AMNet site (top) and 2-hour GOM and PBM2.5 concentrations in pg/m3 for each AMNet site (bottom) in 2017. Horizontal lines in each plot represent the respective 2017 median values.

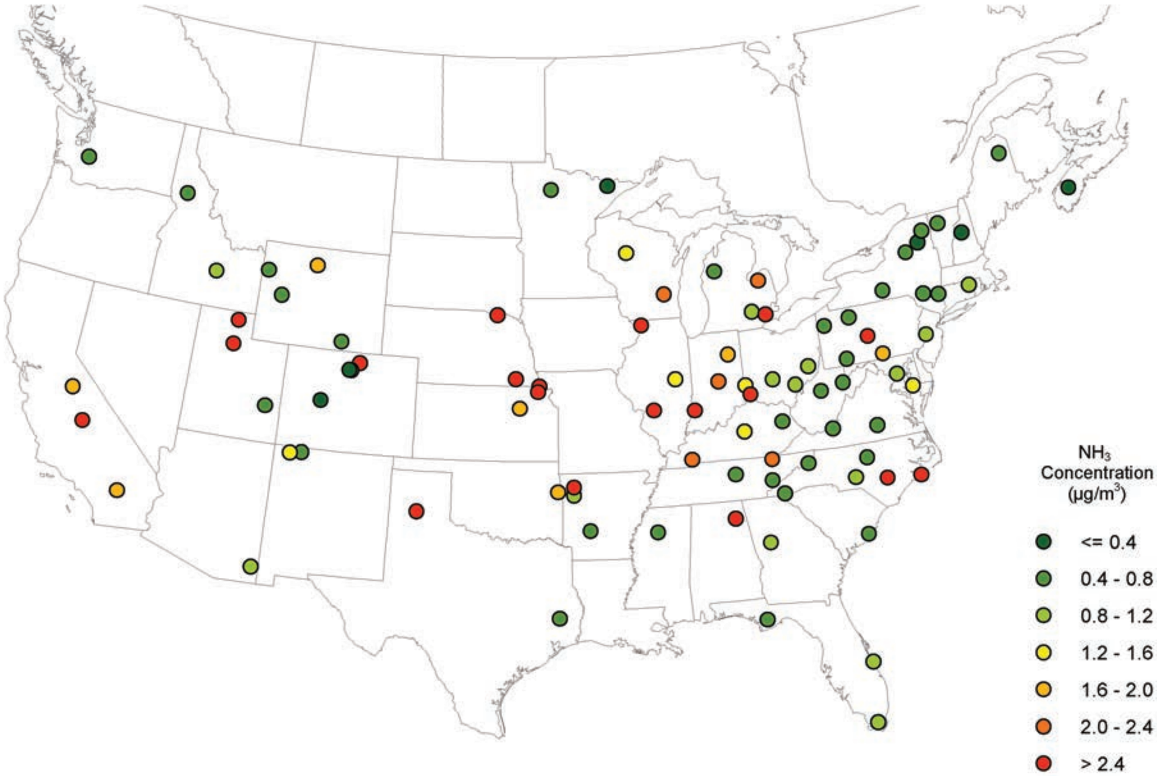
Ammonia Monitoring Network (AMoN)

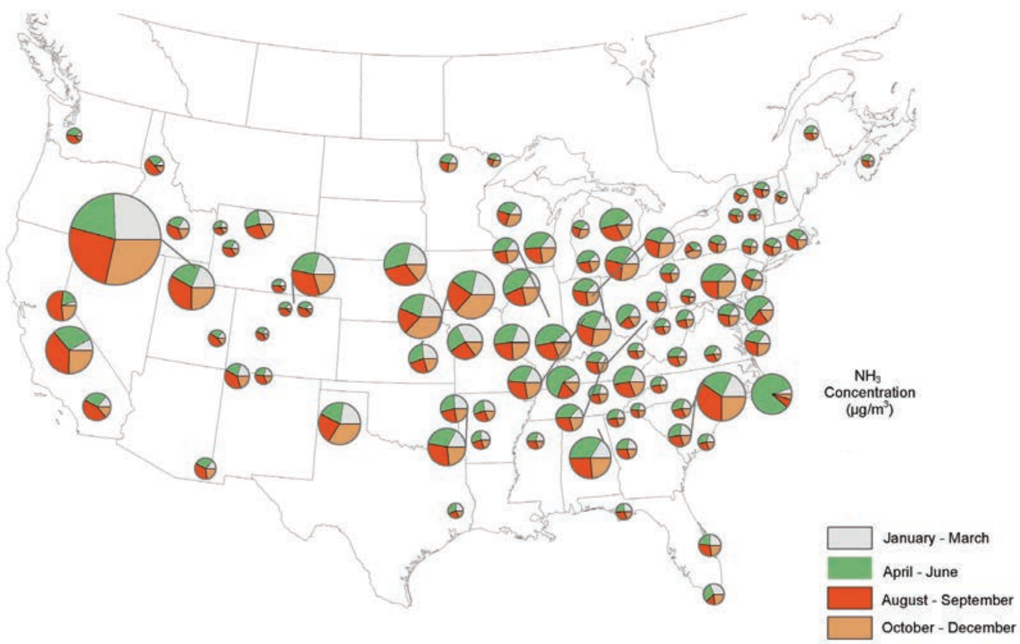
The AMoN measures atmospheric concentrations of ammonia (NH_3) gas. The network uses a passive diffusion-type sampler. This allows for cost-effective, accurate, and simple measurements. Observations are made over a two-week period with some sites collecting additional quality assurance samples. This provides an integrated and quality-assured estimate of ammonia in the air. These data are used to assess both long-term NH_3 trends and changes in atmospheric chemistry and provide information for model development and verification.

As of December 2017, there were 101 AMoN sites. Data from the AMoN are available on the NADP website (http://nadp.slh.wisc.edu/AMoN/).

The figures on page 31 show the distribution and seasonality of gaseous ammonia concentrations for each site meeting completeness criteria. In 2017, 94 of 101 active sites met these criteria. In the top figure, circles represent annual average concentrations in micrograms per cubic meter ($\mu g/m^3$) at each site. In the bottom figure, the relative concentration for each site is shown for each calendar quarter. The size of the wedge is the relative percentage for the quarter. The area of the pie chart is proportional to the annual average for the site.







Average ammonia concentrations as measured by AMoN (top), and quarterly relative percentage (Q1 = January, February, March, etc.) for each AMoN site (bottom), 2017. Size of the symbol in the bottom plot is relative to the annual concentration.

National Atmospheric Deposition Program

The NADP is the National Research Support Project-3: A Long-Term Monitoring Program in Support of Research on the Effects of Atmospheric Chemical Deposition. More than 250 sponsors support the NADP, including private companies and other non-governmental organizations, universities, local and state government agencies, State Agricultural Experiment Stations, national laboratories, Native American organizations, Canadian government agencies, the U.S. Geological Survey, the U.S. Environmental Protection Agency, the National Park Service, National Oceanic and Atmospheric Administration, the U.S. Fish & Wildlife Service, the Bureau of Land Management, the U.S. Department of Agriculture - Forest Service, and the U.S. Department of Agriculture - National Institute of Food and Agriculture, under agreement no. 2017-39565-27338. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the program sponsors or the University of Wisconsin-Madison.

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Madison, WI: October 2018

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All NADP data and information, including color contour maps in this publication, are available free of charge from the NADP website: http://nadp.slh.wisc.edu. Alternatively, contact: NADP Program Office, Wisconsin State Laboratory of Hygiene, 465 Henry Mall, Madison, WI 53706, Tel: (608) 263-9162, E-mail: nadp@slh.wisc.edu.

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